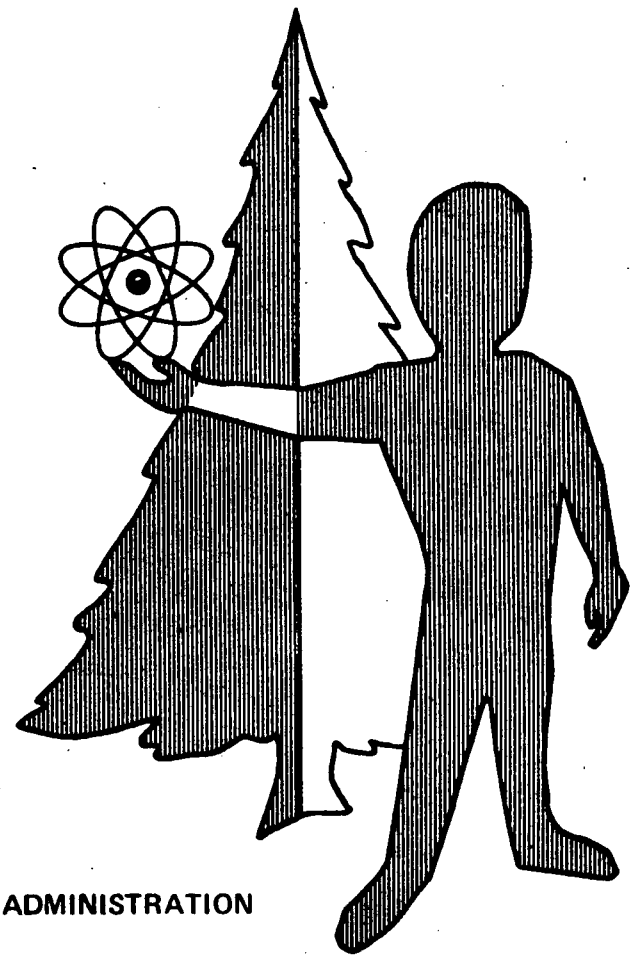
RFP-ENV-74

April 30, 1975

ANNUAL ENVIRONMENTAL MONITORING REPORT

Rocky Flats Plant

JANUARY – DECEMBER 1974



DOW CHEMICAL U.S.A.

Rocky Flats Division

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT AT(29-1)-1106

Environmental Sciences and Waste Control

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Rocky Flats Plant

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Environmental Sciences and Waste Control

Milton A. Thompson, Manager

Environmental Control

Daryl D. Hornbacher, Group Leader

The following changes should be made as indicated (corrections are underscored):

Page 3: Column 2, Paragraph 1 under "Applicable Standards," change "Radioactive."
Line 2: "Administration has published Radioactivity"

Page 4: Column 2, Paragraph 2 under "Analytical Procedures," close sentence and add data.
Line 5: "determined using the atomic absorption method (6)."
Line 6: "Tritium analysis is performed by the method"
Line 7: "of liquid scintillation spectrophotometry."

Page 7: Column 1, Paragraph 2, Remove "of" in Line 11 as indicated.
Line 11: "indicated a total_suspended solids concentration"

Page 9: Column 1, Paragraph 3 under "Soil Sampling" change C to E.
Line 4: "collected in the eastern sector between N54°E"

Page 10: Column 1, Paragraph 4, correct spelling of "Guides."
Line 1: "The Radioactivity Concentration Guides for"

Page 11: Column 1, Paragraph 2, after display equation, change "is" to "as."
Line 7: "millirems, while an average chest X-ray as typified"

Page 13: Table 2, change in Legend from "millimetres" to: ml = millilitres

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Daryl D. Hornbacher, Group Leader

CONTRIBUTORS

I. B. Allen	F. D. Hobbs
C. J. Barker	J. F. Palmer
M. R. Boss	L. J. Walker
D. C. Coonfield	G. J. Werkema
R. R. Gunning	J. M. West

SUBJECT DESCRIPTORS

Effluents	Air
Beryllium	Water
Americium	Soil
Tritium	Standards
Uranium	Liquid Scintillation
Plutonium	Pulse Height Analysis

DOW CHEMICAL U.S.A.
ROCKY FLATS DIVISION
P. O. BOX 888
GOLDEN, COLORADO 80401

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U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Rocky Flats Plant

January through December 1974

Environmental Sciences and Waste Control
Milton A. Thompson and Daryl D. Hornbacher

INTRODUCTION

The Rocky Flats Plant (Golden, Colorado) is owned by the U. S. Government and operated by Dow Chemical U. S. A. under contract with the U. S. Energy Research and Development Administration (formerly the U. S. Atomic Energy Commission), Washington, D. C. The plant is located in Jefferson County, Colorado, some 32 kilometres (about 20 miles) northwest of Denver (Figure 1). (Figures appear at end of text, beginning on Page 23.)

Prior to 1974, the plant site consisted of about 10.1 square kilometres (km^2) of fenced property. At the approximate center of the site is a 1.6 km^2 controlled area that contains all of the plant's major structures. During 1974, 16.2 km^2 of additional land was purchased around the perimeter of the plant site to act as a buffer zone. Currently, the plant site consists of 26.3 km^2 (Figure 2).

The Rocky Flats Plant is primarily a radioactive metal fabrication and chemical processing plant. Its mission involves foundry, fabrication, plutonium recovery and purification operations, and associated support functions, including research and development.

The Rocky Flats Plant is located on a high plateau near the eastern foothills of the Rocky Mountains. Assorted low-growing prairie grasses, prickly pear, and spanish bayonet cactus constitute the main ground cover. Cottonwood trees grow adjacent to the watercourses.

Surface water runoff from the Rocky Flats Plant is from west to east. Runoff is carried from plant property by three major drainage basins which are tributary to Walnut Creek on the north, and Woman Creek to the south. The south fork of Walnut Creek is the main effluent watercourse. The confluence of the north and south forks of Walnut Creek is 1.1 km west of the plant's new eastern boundary. Great Western Reservoir, a major water supply for the city of Broomfield, is about 1.6 km east of the confluence. The north fork of Walnut Creek, south fork of Walnut Creek, and Woman Creek watercourses are designated A, B, and C, respectively (Figure 3). Woman Creek flows east from Rocky Flats into Standley Lake or it can be diverted into Mower Reservoir, a source of irrigation water. Standley Lake is the water supply for the city of Westminster and portions of the Thornton-Northglenn area.

The environmental monitoring program at the Rocky Flats Plant (RFP) is the responsibility of the Environmental Sciences and Waste Control Department. The information and data contained in this report were released monthly to the Rocky Flats Area Office of the U. S. Energy Research and Development Administration (USERDA), Golden, Colorado; the Division of Occupational and Radiological Health of the Colorado Department of Health in Denver, Colorado; the Regional

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Office of the Environmental Protection Agency (Denver); and the Health Departments of Boulder and Jefferson counties in Colorado.

The Colorado Department of Health also conducts air, soil, and water sampling around the Rocky Flats site as a portion of its statewide surveillance program. The Jefferson County Health Department performs monthly sewage plant effluent sampling and analysis and has a continuous particulate air sampler on the plant site operated by the Colorado Department of Health. The Health and Safety Laboratory, New York, of the U. S. Energy Research and Development Administration conducts particulate air sampling at three locations in the vicinity of the Rocky Flats Plant (RFP) and periodically performs soil sampling and analysis. Additional monitoring is performed by the U. S. Environmental Protection Agency (USEPA).

Unless otherwise noted, all references in this report to uranium (U) include the isotopes U-233, U-234, U-235, and U-238. References to plutonium (Pu) pertain to the isotopes Pu-238, Pu-239, and Pu-240.

SITE CLIMATOLOGY

Annual precipitation recorded at the site during 1974 was 34.9 centimetres (cm). For the 22-year period, 1952 through 1974, the average annual rainfall was 40.0 cm. The extreme temperatures recorded during 1974 were 35 and −22 °C, with an annual mean temperature of 11 °C. The mean wind velocity was 13.4 km per hour, with a peak gust of 127.2 km per hour on December 18, 1974.

Hourly observations during 1974 showed that the predominant wind direction was from the northwest. This direction accounted for 22% of the wind observations. The 1974 Wind Rose is shown in Figure 4.

Hourly wind data from January 1972 through August 1974 have been summarized into stability categories and annual frequencies by Loren W. Crow, certified consulting meteorologist from Denver, Colorado. The following summary remarks (not in paragraph sequence) are excerpted from the report (1),[1] and will be refined by Crow as additional data become available. Text additions in brackets [ ] are inserted by Rocky Flats authors.

"Neutral stability conditions with corresponding well-mixed airflow prevails slightly over 50 percent of the hours per year at both Rocky Flats and Denver Airport (Stapleton International Airport). Under such conditions, there is a wide range of directions of flow with a slightly higher frequency in the direction range from west-northwest through northeast.

"During stable conditions there is a marked difference in the patterns of airflow emanating from the Denver metropolitan area and the airflow emanating from Rocky Flats. The confluence of drainage air from both areas generally occurs above the lower part of the Platte River Valley to the west and north of Brighton, Colorado. There is very little vertical mixing during stable air periods. Stable conditions prevail for 35 and 40 percent of all hours.

"The least frequent stability class is unstable conditions. Most of the unstable hours occur in the summer time when there is strong vertical mixing produced by high surface temperatures during daylight hours. The unstable hours constitute less than 15 percent of the total hours per year. Unstable conditions generally occur when air is moving toward the mountains and with corresponding rapid vertical mixing.

"Repeatable patterns of airflow can be identified in five separately defined categories. Days which are primarily controlled by synoptic airflow and turn-around days are the most frequent types. Almost all dense pollution occurs on turn-around type days in the Denver metropolitan area. The effluents which moved away from either Rocky Flats or the Denver metropolitan area under downslope stable conditions seldom move back over the same source point with more than a small fraction of the initial density. This is particularly true at Rocky Flats where effluents emanate from essentially a point source.

"High wind speeds ≥20 mph [32 km per hour] occur between 500 and 600 hours per year at

[1] References given in parentheses are listed at end of text (Page 11).

Rocky Flats. The dominant direction of airflow for such winds is from the west or northwest. Such strong winds are capable of picking up and re-transporting dust particles which have previously obtained some collected burden of pollutant material from a localized source. Densities of gaseous pollutant material or the very small and slowly falling particles containing toxic pollutants would be very low under such strong wind conditions at distances of more than a few hundred yards."

"Under *STABLE* conditions there is a notable difference in airflow between Denver Airport and Rocky Flats. There is a prominent peak frequency of airflow from south-southwest at Denver. By contrast, the range of wind direction under *STABLE* conditions at Rocky Flats carries a broad level of nearly equal frequency from southwest through northwest. In most instances, the *STABLE* air temperature near the ground above the lower portions of the Platte River Valley near the north end of Denver is colder during the morning hours than at Rocky Flats. *STABLE* but relatively warmer air moving past Rocky Flats would establish its own equivalent level of buoyancy and move toward the Platte River at a higher elevation than the colder air near the surface in the Denver metropolitan area. In other instances, *NEUTRAL* stability conditions with corresponding rapid dispersal of effluents will prevail at Rocky Flats while colder *STABLE* air and its collected burden of pollutants will remain near the ground to the north of Denver. Under such circumstances, there would be no mixing downward of effluents from Rocky Flats into the *STABLE* air below.

"Under *NEUTRAL* and *UNSTABLE* conditions the frequency distribution of directions is somewhat similar at both locations. However, Rocky Flats has a greater frequency of *UNSTABLE* air motion ranging from the northeast through south-southeast directions. The relatively low frequency of *UNSTABLE* conditions with corresponding rapid vertical mixing should limit any surface deposition of material emanating from Rocky Flats to the first one to three miles [1.6 to 4.8 km] from the source toward higher ground to the west of the plant."

SUMMARY

Results of the environmental monitoring program in the Rocky Flats vicinity indicate that the average environmental concentrations of plutonium in air and water during 1974 were less than 1.7% of applicable U. S. Energy Research and Development Administration Radioactivity Concentration Guides. Average concentrations of americium-241 and hydrogen-3 (tritium) in water samples were less than 1.0% of applicable USERDA Radioactivity Concentration Guides.

MONITORING DATA COLLECTION, ANALYSIS, AND EVALUATION

Applicable Standards

The U. S. Energy Research and Development Administration has published Radioactivity Concentration Guides (RCG) (2) governing concentrations of radionuclides in air (RCG_a) and water (RCG_w) accessible for intake by occupationally exposed individuals, incidentally exposed individuals, and the population at large. These guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) in Washington, D. C. Numerical values of the standards are cited in appropriate tables presented elsewhere in this report.

All radionuclides in plant effluents and environmental samples are assumed to be soluble for purposes of comparison with appropriate concentration standards. The assumption serves as an additional safeguard since the radioactivity concentration guides for soluble radionuclides are more restrictive than those for insoluble radioactive materials.

The Rocky Flats administrative guide value for concentrations of total long-lived alpha activity in airborne effluents from plutonium areas is 60×10^{-15} microcuries per millilitre (μCi/ml), which is the soluble plutonium concentration guide value for an individual in an uncontrolled area.

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The Rocky Flats administrative guide value for soluble uranium airborne effluents from uranium areas is 20×10^{-12} μCi/ml. The concentration of uranium plus plutonium in effluent water at the plant boundary was maintained below 1667×10^{-9} μCi/ml, the soluble plutonium concentration guide value for a suitable sample of an exposed population. The comparable standard for americium-241 is 1330×10^{-9} μCi/ml. The Environmental Protection Agency's discharge limitation for beryllium is 10 grams per stationary source in a 24-hour period (3). The Rocky Flats Plant is considered a single stationary source.

A water discharge permit (4) was issued to the Rocky Flats Plant by the U. S. Environmental Protection Agency (EPA) under the National Pollutant Discharge Elimination System (NPDES) permit program in October 1974. The NPDES permit establishes effluent concentration limitations for nitrate, phosphate, 5-day biochemical oxygen demand, fluoride, dissolved oxygen, chlorine residual, total suspended solids, fecal coliform bacteria, total chromium, oil and grease, and pH in the sewage treatment plant discharge, and for nitrate and pH in the discharge from holding pond A-3 in Walnut Creek. Numerical values of the effluent concentration limitations are cited as appropriate in the tables presented within the report.

Background Radioactivity

Although the standards for radioactivity relate to concentrations above background, the measurements given in this report include contributions from both fallout and radioactive materials which are normally found in air, soil, and water on the eastern slope of the Colorado Rockies. Typical background values for radioactive materials found in the region are listed in Table 1. (Tables follow at end of text, beginning on Page 12.) These values were determined by analysis of air and soil samples collected west of the plant site. Water samples were collected from Boulder, Cherry Creek, Gross, and Ralston reservoirs. Analysis for uranium, plutonium, and americium was performed by Battelle Pacific Northwest Laboratory, Richland, Washington. Tritium analysis was conducted by the Rocky Flats Environmental Analysis Laboratory.

Analytical Procedures

Plutonium was determined in effluent and environmental samples by a radiochemical technique in which plutonium was separated from other radionuclides by ion exchange chromatography (5), electroplated on a stainless steel disk, and analyzed by pulse-height spectrometry. The chemical recovery of plutonium for this analytical procedure is determined by adding a standard aliquot of a plutonium-236 tracer.

Uranium and americium analyses are performed in the same manner as the plutonium analysis with the exception of the use of uranium-232 and curium-244 tracers. Effluent beryllium concentrations are determined using the atomic absorption method (6). ~~of liquid scintillation spectrophotometry~~ Tritium analysis is performed by the method

Detection Limits

Table 2 shows nominal values for the minimum detectable concentrations (MDC) of materials in various media. The values shown are for typical sample volumes as used in the Rocky Flats monitoring program. For any individual sample, the MDC may be greater or smaller, depending on the size of the sample that was collected and analyzed. Table 2 also lists the various nonradioactive and radioactivity concentration guide values applicable to airborne and waterborne effluent releases from the Rocky Flats Plant.

Data Reduction

Throughout the data presented, samples that had concentrations below the minimum detectable concentration (MDC) were considered as having the MDC for averaging purposes. When one or more MDC values are included in a set of values, the computed mean value of that set is indicated by a *less than* sign (<). The error term (±%) associated with concentrations (C_{max}) represents the counting error at the 95-percent confidence level. The average concentrations (C_{avg}) are represented by pairs of numbers that define the 95-percent confidence interval for $C_{average}$. This interval is centered at $\bar{c}$ and is bounded by the percentage

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deviations from $\bar{c}$. The probability (P) that C_{avg} lies within the stated interval is 95 percent, or:

$$P\left[\left(\bar{c} - t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_1^2 - n\bar{c}^2}{n(n-1)}}\right) \leq C_{avg} \left(\bar{c} + t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_1^2 - n\bar{c}^2}{n(n-1)}}\right)\right] = 0.95$$

Where,

$\bar{c}$ = the arithmetic mean of observed concentrations and is volume weighted whenever the volume is measured

$t_{0.975}$ = value taken from a standard t-test table

n = the number of samples

c_1 = an individual observed concentration

Quality Control

A rigorous analytical quality control program was established in the Rocky Flats Environmental Analysis Laboratory in July 1974. By the end of 1974, approximately 15% of all samples analyzed by the Laboratory were quality-control samples. The preparation of standard samples and numerical analysis of sample results are conducted by the Rocky Flats Chemical Standards Laboratory. A summary of the Rocky Flats Environmental Analysis Laboratory performance during 1974 is shown in Table 3.

In addition, the Rocky Flats Environmental Analysis Laboratory participates in a laboratory cross-check program sponsored by the U. S. Environmental Protection Agency, Quality Assurance Branch, Las Vegas, Nevada. Analyses for the various radionuclides included in the EPA cross-check program show that results, to date, have been within the expected analytical precision. This is documented by updated control charts and interlaboratory comparison reports furnished to each laboratory participating in the program.

Airborne Effluent Monitoring

Exhaust air from Rocky Flats production and research facilities is sampled continuously. In the plutonium facilities, a minimum of two sampling points and at least one continuous monitoring and alarm system are located in each exhaust air-duct downstream from the final stage of filters. The filterable particulate component of the sample stream is collected on Gelman Type-E glass fiber filter media. Particulate samples are collected three times each week from plutonium-, uranium-, and beryllium-facility exhaust stacks. During 1974, each sample was analyzed for total long-lived alpha-emitting radionuclides and beryllium, as appropriate. In addition, samples from plutonium facilities are composited weekly and analyzed, specifically for plutonium. Table 4 shows the quantities of radionuclides and beryllium released from plant facilities during 1974.

Ambient Air Monitoring

Ambient air is sampled continuously at 12 locations within and on the perimeter of the Rocky Flats Plant exclusion area (Figure 5). Gast Model 0465-V4A-025 sampling pumps are used to draw air through Gelman Type-E glass fiber filter media at a sampling rate of 1 litre per second (l/s). The sample filters are collected three times each week and analyzed for total long-lived alpha-emitting radionuclides. The sample collected on Wednesday of each week is further analyzed for total long-lived beta-emitting radionuclides. After initial analysis, the samples are composited monthly and analyzed for plutonium.

Four additional air samplers (S-22, S-51, AF-83, and AC-84 in Figure 5) have been operated as pilot models for replacement units for all ambient air samplers. These samplers are equipped with Rotron Cyclonaire Model CHE-3 air movers. Air is drawn continuously at a sampling rate of 19 l/s through 20 X 25-cm Delbag Microsorban filter media. The samples are collected weekly,

composited, and analyzed monthly specifically for plutonium.

Table 5 shows the volume-weighted, arithmetic average concentrations of plutonium in airborne particulates at sample stations within the plant's exclusion area during 1974. The average concentration of plutonium in ambient air at all exclusion area stations during 1974 was $0.608 \pm 39\% \times 10^{-15}$ μCi/ml. This concentration was equal to 1.01% of the RCG_a for soluble plutonium in ambient air accessible to incidentally exposed individuals.

The volume-weighted, arithmetic average concentrations of long-lived beta-emitting radionuclides in airborne particulates of sample stations within the exclusion area during 1974 are given in Table 6. The annual average concentration of long-lived beta emitters at all exclusion area stations during 1974 was less than $0.204 \pm 8\% \times 10^{-12}$ μCi/ml. This concentration was less than 0.20% of the RCG_a for total long-lived beta activity in ambient air accessible to incidentally exposed individuals.

Airborne particulate samples are collected at 10 locations surrounding the Rocky Flats Plant between 3 and 6 km (2 and 4 miles) from the plant center (Figure 6). Air is drawn continuously through Delbag Microsorban filter media at a 19 l/s sampling rate. Samples are collected weekly, composited monthly, and radiochemically analyzed specifically for plutonium. Table 7 shows the volume-weighted monthly and arithmetic average concentrations of plutonium in filterable airborne particulates at the 2- to 4-mile sample stations. The annual average concentration of plutonium in ambient air at those stations during 1974 was less than $0.058 \pm 39\% \times 10^{-15}$ μCi/ml. That concentration was less than 0.29% of the RCG_a for soluble plutonium in public areas. The monthly average concentrations of plutonium at those stations are graphed in Figure 7.

Airborne particulate samples are collected at 9 locations (●) in or near population centers in the vicinity of the Rocky Flats Plant. Those locations, shown in Figure 6, include Boulder, Broomfield, Coal Creek, Denver, Golden, Lafayette, Marshall, Wagner, and Westminster. Air is drawn continuously through Gelman Type-E glass fiber filter media at a sampling rate of 1 litre per second. Samples are collected weekly and analyzed for total long-lived alpha- and beta-emitting radionuclides. The weekly samples are composited monthly and analyzed for plutonium.

The average concentrations of plutonium at community air-sample stations during 1974 are shown in Table 8. During that period, the average concentration of plutonium in population centers near the Rocky Flats Plant was less than $0.343 \pm 92\% \times 10^{-15}$ μCi/ml. That concentration was less than 1.72% of the RCG_a for soluble plutonium in public areas. Analysis results from two samples (Golden in May and Coal Creek in October) were responsible for elevating the annual average above typical background concentrations for the area. Both sampling locations are southwest of the plant site and not in the direction of prevailing winds.

Table 9 presents the average concentrations of long-lived alpha and beta-emitting radionuclides in ambient air at community samplers during 1974. The annual average concentrations of long-lived alpha and beta emitters at all community samplers were less than $2.0 \pm 7\% \times 10^{-15}$ μCi/ml and less than $0.148 \pm 6\% \times 10^{-12}$ μCi/ml, respectively. These concentrations were less than 10.0% and less than 0.45% of the applicable RCG_a values for total long-lived alpha and beta activity in public areas.

Waterborne Effluent Monitoring

During 1974, waste water discharged from the Rocky Flats Plant consisted of filter backwash from the water-treatment plant, treated sanitary waste, and cooling-tower blowdown and steam condensate. From January through November sanitary wastes were treated in a secondary treatment facility. A tertiary treatment system was completed and operational in December 1974. Solids are decomposed in an activated sludge digestor. After drying, the contents of the digestor are packaged in 55-gallon drums and are shipped to the USERDA waste-storage facility in Idaho.

Liquid sanitary wastes are discharged to the B-branch (southernmost) of Walnut Creek (Figure 3). Three holding ponds, B-1, B-3, and B-4 on the B-branch of Walnut Creek, provide additional treatment of water discharged from the sanitary waste treatment facility. Ponds B-1 and B-3 are equipped to impound water for analysis prior to release and to prevent accidental liquid releases. Pond B-2 is isolated from the stream and is used to impound process wastewater. The process wastewater is then pumped to Pond A-2 for storage.

Average concentrations of chemical and biological parameters of routine sewage-plant effluent samples collected during 1974 are shown in Table 10. This table is divided into three sections which list the appropriate Colorado Department of Health standards and USEPA-NPDES permit limitations in effect during 1974. On one occasion during 1974, NPDES effluent concentration limitations were exceeded at the sewage-treatment plant outfall. In October, analysis of a 24-hour sample indicated a total suspended solids concentration of 53 parts per million, as compared to the daily maximum limitation of 45 parts per million.

The A-branch of Walnut Creek receives natural runoff from the north side of the plant site. Two holding ponds, A-1 and A-3, located on the A-branch of Walnut Creek are used to impound water for analysis prior to release. Pond A-2 is isolated from the stream and is used to store process wastewater.

Water treatment plant-filter backwash is discharged to Woman Creek. One holding pond, C-1, is located on Woman Creek and could be used to impound accidental liquid releases. No impoundment of effluent waters on any of the three watercourses was necessary during 1974.

Water is sampled continuously and collected daily from the outfalls of Ponds A-3, B-4, and C-1 (Figure 3). The daily samples are composited into weekly samples for analysis of plutonium, uranium, and americium. Plutonium and uranium are isolated from other long-lived alpha emitters by ion exchange chromatography (5), and their concentrations determined by alpha pulse-height spectrometry. The chemical recovery of plutonium for the analytical procedure is determined by adding a plutonium-236 tracer. Uranium and americium recovery is determined by uranium-232 and curium-244 tracers.

Concentrations of plutonium, uranium, and americium in water sampled at the outfalls of Ponds A-3, B-4, and C-1 are shown in Table 11. The annual average-concentrations of plutonium in the outfalls of Ponds A-3, B-4, and C-1 during 1974 were:

$0.253 \pm 42\% \times 10^{-9}$ μCi/ml
(0.02% of the RCG_W),

$1.78 \pm 29\% \times 10^{-9}$ μCi/ml
(0.11% of the RCG_W), and less than

$0.155 \pm 46\% \times 10^{-9}$ μCi/ml
(<0.01% of the RCG_W), respectively.

The monthly average-plutonium concentrations in Pond B-4 are graphed in Figure 8. Uranium and americium concentrations in these ponds were less than 0.05% of the applicable RCG_W.

Walnut Creek is sampled continuously at Indiana Street, which is downstream from the confluence of the stream tributaries and approximately at the plant's east boundary. These samples are composited weekly and analyzed for plutonium, uranium, and americium. Results of the analyses are shown in Table 12. The 1974 average concentrations of plutonium, uranium, and americium at the Indiana Street location were:

$0.843 \pm 48\% \times 10^{-9}$ μCi/ml
(0.05% of the RCG_W),

$3.691 \pm 33\% \times 10^{-9}$ μCi/ml
(0.04% of the RCG_W), and less than

$0.023 \pm 48\% \times 10^{-9}$ μCi/ml
(<0.01% of the RCG_W), respectively.

Tritium

Tritium was released in plant effluent water during 1973 and 1974 as the result of processing

a shipment of plutonium during 1973 that, unknown to Rocky Flats Plant personnel, had been contaminated with tritium by another USERDA facility. To prevent recurrence of such an incident, more stringent procedures have been established to detect tritium and other radionuclides in all incoming shipments and in plant effluents. This incident has been investigated by the USAEC (7) and by the (USEPA) (8). Findings from both agencies showed that the quantity of tritium from Rocky Flats presented no hazard to human health.

Water sampled continuously at the outfalls of Ponds A-3, B-4, C-1, and Walnut Creek at Indiana Street was analyzed daily for tritium by liquid-scintillation spectrometry. Also, water samples collected weekly at Great Western Reservoir and Standley Lake were analyzed for tritium. The average concentrations of tritium in the water samples analyzed during 1974 are summarized in Table 13. The monthly average tritium concentrations are graphed for Walnut Creek in Figure 9 and for Great Western Reservoir and Standley Lake in Figure 10. The tritium concentrations at all the above locations were less than 0.608% of the applicable RCG_W.

Groundwater Monitoring

A total of 15 wells were drilled on the plant site in 1960, 1966, and 1971. Three of the wells are approximately 46 metres deep (150 feet); they provide information on water movement in bedrock formations. The remainder range from 6 to 9 metres deep (about 20 to 30 feet) and all are located generally near three on-site solar evaporation ponds and downstream from the holding ponds. To improve the reliability of the well-water sampling program and provide additional information, the 15 old wells are being redrilled, and will be uniformly cased and grouted to prevent the entry of surface water. In addition, 22 new wells were drilled during 1974. The locations of all 37 wells are shown in Figure 11.

Those wells that contained water were sampled quarterly to determine whether any detectable movement was evident of chemicals or radioactive materials of plant origin into the water-bearing strata underlying the site. During the first two quarters of 1974, the well-water samples were analyzed for fluoride, nitrate, pH, total solids, and plutonium. During the last two quarters of 1974, the analytical program was expanded to include additional analysis for conductivity, hardness, nitrite, total long-lived alpha and beta, and tritium. Several of the new wells were not completed until the third quarter. Therefore, Table 14 gives the analysis result for the last quarter of 1974. Historically, the samples have indicated that no movement exists of plutonium into the groundwater of the plant site. However, some nitrate has appeared in the wells surrounding the solar evaporation ponds.

Regional Water Monitoring

Water samples are collected weekly from two reservoirs and nine tap-water locations around the Rocky Flats and greater Denver areas. The reservoirs included Great Western Reservoir, which is the Broomfield water supply, and Standley Lake, which serves Westminster and portions of the Thornton-Northglenn area (Figure 3). Tap or treated water is collected from the surrounding communities of Arvada, Boulder, Broomfield, Denver, Golden, Lafayette, Louisville, Thornton, and Westminster. The weekly samples are composited monthly and analyzed for uranium plus plutonium, and specifically for plutonium. These data are summarized in Table 15. The annual, average plutonium concentration was less than $0.02 \pm 0\% \times 10^{-9}$ μCi/ml in reservoir water samples and less than $0.07 \pm 89\% \times 10^{-9}$ μCi/ml in community water samples. These concentrations were less than 0.01% of the RCG_W for soluble plutonium in public water supplies.

In September 1974, single water samples were collected from 28 additional area reservoirs, lakes, and streams. Samples were collected to a distance some 32 km (20 miles) from the plant and analyzed for uranium plus plutonium, and specifically for plutonium. The data presented in Table 16 show that the average plutonium concentration in those samples was less than $0.13 \pm 51\% \times 10^{-9}$ μCi/ml.

That concentration was less than 0.01% of the RCG_W for soluble plutonium in public areas.

Soil Sampling

Fifty-seven routine soil samples are collected annually in the plant environs. Samples are collected each 18 degrees of arc on circles of radii of 1.6, 3.2, and 8 km (1, 2, and 5 miles), concentric with the center of the plant, and analyzed for plutonium. The geometry of all soil samples is carefully controlled by driving a 10 by 10-cm cutting tool 5 cm into undisturbed soil and excavating the soil contained within the tool cavity.

Sample preparation and analysis for plutonium is conducted using the method reported by Talvitie (9). The samples are oven-dried at 120 °C, then weighed, homogenized, and sieved to remove the coarser rubble. Ten grams of pulverized soil are utilized for plutonium analysis. The chemical recovery of plutonium for the analytical procedure is determined by adding a plutonium-236 tracer. The analytical results are reported from the laboratory in units of disintegrations per minute per gram of fines. These results must be corrected to account for the coarse material removed by sieving. To accomplish this, the laboratory result is multiplied by the ratio of grams fines to grams total sample. The corrected result, in units of disintegrations per minute per gram sample, is converted to picocuries per gram sample. All samples collected in 1974 represent a 100 cm^2 area. No Federal Standards for the concentration of plutonium in soil exist.

The 1974 soil data are displayed on a map in Figure 12. This map indicates that the majority of above background values were found in samples collected in the eastern sector between N54°E and E54°S. The distribution of plutonium in this sector is related to the westerly, prevailing winds at Rocky Flats.

Aerial Radiological Survey

During May and October 1972, an Aerial Radiological Survey of the Rocky Flats Plant and environs was conducted by EG&G, Inc., Las Vegas, Nevada. The following summary remarks (not in paragraph sequence) are excerpted from their 1974 report (10).

"The survey was conducted to measure the total terrestrial gamma-radiation exposure rates within the energy range $0.05 \leqslant E\gamma \leqslant 3.0$ MeV in the vicinity of the Rocky Flats Plant.

"During the May survey, a series of 0.20-nautical-mile (1,216 feet) [371 metres] spaced lines were flown directly over the Rocky Flats Plant. This detailed survey covered an area of approximately 16 square miles (8 X 2 mi.) [42 square km]. On 6 October 1972, a series of 13 lines were flown at one-nautical-mile intervals, each 10 to 20 miles long [16 to 32 km long].

"A high-sensitivity detection system collected gamma-ray spectral and gross-count data. The data were then computer-processed into a map of an area approximately 200 square miles [520 square km], showing isoexposure contours 3 feet [about 1 metre] above the ground.

"The 200-square-mile [520 square km] aerial survey of the area outside the perimeter fence of the Rocky Flats Plant revealed that both the concentration and relative abundance of radioactive isotopes are consistent with normal terrestrial background radiation. The 3-foot level exposure rates mapped during the survey were mostly in the 14-to-22 μR/hr range."

"The detailed survey within the plant perimeter shows exposure rates from 20 to 100 μR/hr. . . . ." "The area of increased exposure rates appears to be centered over the buildings within the perimeter of the site. This indicates the increased exposure rates are caused by fissionable material stored in the buildings or close to them."

ASSESSMENT OF PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

The Rocky Flats Plant has always minimized all radioactive and nonradioactive effluents discharged from the plant site to concentrations substantially

less than the allowable limits. Plant effluents containing uranium, plutonium, and tritium may contribute radiation exposure to the general population.

Plutonium does not occur naturally; therefore, its presence in the environment can be attributed to either the Rocky Flats Plant or to fallout from nuclear testing. Tritium and uranium are both found naturally, and while most of the tritium in the local environment may be due to plant operations, this isotope may also be due to fallout. Uranium is found naturally and in many areas in the state is present in much higher concentrations than found locally. Gross alpha-concentration level in the water upstream from the plant at Ralson Reservoir near Golden is higher than that in the water leaving the plant.

To calculate dose assessment, the most restrictive Radioactivity Concentration Guide (RCG) values have been used. It has been assumed that all radioactive material released from the plant was in water-soluble (rather than insoluble) form, that all of the material was inhaled or ingested completely and instantaneously taken up by the body, and that all of the material was retained in the body. These assumptions will grossly over-estimate the dose to the population. For example, not all of the material is in the water-soluble form, nor is all of the material retained in the body. Plutonium and uranium compounds typically are not readily water-soluble. Thus the estimates of dose to the general public will be higher than those which actually exist.

The Radioactivity Concentration Guides for soluble plutonium are those concentrations in air and water that, after fifty years continuous exposure, will result in a specific accumulation in the bone of an exposed individual. Based on the ICRP recommendations, the maximum accumulated amount of plutonium allowed in the bone is 0.001 μCi (11). This amount of plutonium will give the maximum allowable dose to the bone of one rem per year. (The acronym, *rem*, refers to *roentgen equivalent man*, a unit of dose of ionizing radiation.)

Tritium rapidly exchanges with normal hydrogen in body tissue containing water. Therefore, the critical organ for tritium is body tissue (11). The radiation protection standard for tritium is 0.17 rem.

The dose commitment to the general population was calculated by multiplying the appropriate radiation protection standard (1 rem per year for plutonium and 0.17 rem per year for tritium) by the ratio of the average concentration of plutonium in air or plutonium in water (C_{avg}) and the appropriate RCG value. For example, the dose commitment due to plutonium in community air was calculated as follows:

$$\text{Dose (rems/year)} = \text{Standard} \times \frac{C_{avg}}{RCG_a}$$

$$= 1 \frac{\text{rem}}{\text{year}} \times \frac{0.343 \times 10^{-15}\ \mu\text{Ci/cm}^3}{20.0 \times 10^{-15}\ \mu\text{Ci/cm}^3}$$

$$= 0.01715 \text{ rem per year}$$

$$= 17.2 \text{ millirems per year}$$

The calculated dose commitments, based on samples collected near the plant-site perimeter and in the adjacent communities, are given in Table 17. The total estimated dose commitment from plutonium and tritium in air and water at the plant-site perimeter was found to be less than 3.82 millirems per year. In the surrounding communities, the total estimated dose commitment was calculated to be less than 18.3 millirems per year. As described earlier, analysis results for plutonium from two air samples (Golden in May and Coal Creek in October) were significantly higher than the annual average background concentrations for the area. These two sample results are responsible for the higher calculated dose commitment in the communities as compared to the dose commitment at the plant perimeter. The accumulation of plutonium in the bone of any individual exposed during a 50-year time period was calculated by multiplying the maximum allowable quantity of plutonium (0.001 μCi) by the ratio of the community air C_{avg} value and the RCG_a value:

$$\text{Accumulation} = 0.001\ \mu\text{Ci} \times \frac{C_{avg}}{RCG_a}$$

$$= 0.001\ \mu\text{Ci} \times \frac{0.343 \times 10^{-15}\ \mu\text{Ci/cm}^3}{20.0 \times 10^{-15}\ \mu\text{Ci/cm}^3}$$

$$= 1.72 \times 10^{-5}\ \mu\text{Ci per individual}$$

After 50 years of continuous exposure to air containing 0.343×10^{-15} μCi of plutonium per cubic centimetre (cm^3), an exposed individual would have an accumulation of 1.72×10^{-5} μCi and an annual dose commitment in the fiftieth year of 17.2 millirems.

The total dose available to any member of the general population living continuously in communities near the plant site was conservatively calculated to be less than one tenth the natural background found in Colorado. For comparative purposes, the average background is between 200 and 250 millirems, while an average chest X-ray as typified by an annual TB checkup delivers about 100 millirems.

Approximately 1.54 million people live within an 80-kilometre arc around the Rocky Flats Plant. If the dose commitment of <18.3 millirems per year estimated for the closest populated areas were available over the entire area, then the total dose commitment to this population would be <28,182 man-rems (total population times dose commitment). In comparison, natural background of 200 to 250 millirems per year would contribute from 308,000 to 385,000 man-rems to this same population.

REFERENCES

1. Loren W. Crow. *Characteristic Airflow Patterns near Rocky Flats Plant and their Relationship to Metropolitan Denver.* Denver, Colorado. December 16, 1974.
2. *Standards for Radiation Protection.* AEC Manual, Chapter 0524. U. S. Atomic Energy Commission, Washington, D. C. 1968.
3. *National Emission Standards for Hazardous Air Pollutants.* 40-CFR Part 61. Subpart C. U. S. Environmental Protection Agency, Washington, D. C. April 6, 1973.
4. *U. S. Environmental Protection Agency.* NPDES Permit No. CO-0001333. National Pollutant Discharge Elimination System, Washington, D. C. September 6, 1974.
5. D. L. Bokowski. "Standard Laboratory Procedures for the Determination of Radioactivity and Chemical Concentrations in Environmental and Bioassay Samples." Internal Report, USAEC RFP-2039. 1974.
6. D. L. Bokowski. "Rapid Determination of Beryllium by a Direct-Reading Atomic Absorption Spectrometer." *American Industrial Hygiene Association* 29:474-481. 1968.
7. *Investigation of the Tritium Release Occurrence at the Rocky Flats Plant.* U. S. Atomic Energy Commission, Albuquerque Operations Office, Albuquerque, New Mexico. November 26, 1973.
8. *Investigative Report of the 1973 Tritium Release at the Rocky Flats Plant in Golden, Colorado.* U. S. Environmental Protection Agency, Region VIII, Denver, Colorado. 1974.
9. N. A. Talvitie. "Radiochemical Determination of Plutonium in Environmental and Biological Samples by Ion Exchange." *Analytical Chemistry* 43:1827-1830. 1971.
10. *Radiological Survey of the Area Surrounding the Rocky Flats Plant, Golden, Colorado, 3 and 4 May and 6 October, 1972.* Report No. EGG-1183-1641. EG&G, Inc., Las Vegas, Nevada. September 30, 1974.
11. "Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959)." *Health Physics* 3. 1960.

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TABLES 1 through 17

TABLE 1. Regional Background Radioactivity Concentrations.

Radionuclide	Air (× 10^{-15} microcuries per millilitre)	[a]Soil (picocuries per gram)	Water (× 10^{-9} microcuries per millilitre)
Uranium-234, 235, 236	0.0011 ± 0.0004	1.59 ±0.358	< 0.176 ± 0.31
Plutonium-238	< 0.000001 ±	<0.001	< 0.001
Plutonium-239, 240	0.00003 ± 0.000004	0.028 ±0.018	< 0.001
Americium-241	< 0.000011 ± 0.000009	0.012 ±0.013	< 0.002
Tritium (^{3}H)	2000 ±1000	–	460.0 ±460

[a]Soil samples were collected to a depth of 5 centimetres (cm) using a 10 by 10-cm cutting tool.

*.06 d/m/g

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TABLE 2. Radioactive and Nonradioactive Detection Limits and Applicable Standards.

Parameter	Approximate Sample Volume	Approximate Detection Limit (μCi/ml)	Applicable Standard (μCi/ml)	Reference
Stack Samples				
Plutonium	570.5 m^3	0.00016 × 10^{-12}	< = 0.06 × 10^{-12}	RF Guide
Total Long-Lived Alpha	570.5	0.002 ×	< = 0.02 ×	
Total Long-Lived Beta	570.5	0.030 ×	< = 100.1 ×	
Uranium	570.5	0.00016 ×	< = 20.0 ×	
Tritium	6.0	76.7 ×	< = 2.0 × 10^{-7}	
Beryllium	570.5	0.00001 μg/m^3	< = 0.01 μg/m^3	40 CFR 61
Ambient Air Samples				
Plutonium	2,526. m^3	0.00004 × 10^{-12}	< = 0.02 × 10^{-12}	AECMC 0524
Plutonium	11,410.	0.000008 ×	< = 0.02 ×	
Total Long-Lived Alpha	570.5	0.002 ×	< = 0.02 ×	
Total Long-Lived Beta	570.5	0.030 ×	< = 100.1 ×	
Tritium	10.0	2.0 ×	< = 6.6 × 10^{-8}	
Beryllium	570.5	0.00001 μg/m^3	< = 0.01 μg/m^3	40 CFR 61
Beryllium	11,410	0.0000005 μg/m^3	< = 0.01 μg/m^3	40 CFR 61
Effluent Water Samples, Radioactive				
Plutonium	1 litre	0.10 × 10^{-9}	< = 1,667 × 10^{-9}	AECMC 0524
Uranium	1 litre	0.10 ×	< = 10,000 ×	
Americium	1 litre	0.10 ×	< = 1,330 ×	
Tritium	1 litre	460. ×	< = 1,000,000 ×	
Total Long-Lived Alpha	25 millilitres	5.0 ×	< = 40 ×	RF Guide
Soil Samples, Radioactive				
Plutonium	10 grams	0.01 pCi/g	NA	NA
Effluent Water Samples, Nonradioactive				
pH	NA	0 to 14	6.0 to 9.0	NPDES Permit
Nitrate as N	10 ml	0.2 mg/l	< = 20 mg/l	
Phosphorus as P	50	0.2	< = 8	
Fluoride	20	0.2	< = 1.7	
Biochemical Oxygen Demand, 5-Day	10	1.0	< = 25	
Dissolved Oxygen	300	1.0	= > 2	
Total Suspended Solids	100	2.0	< = 25	
Total Chromium	5	0.05	< = 0.1	
Residual Chlorine	10	<0.1	< = 0.1	
Oil and Grease	500	0.1	< = 10	
Fecal Coliforms	10 to 100	0	400 organisms/100 ml (7-Day) 200 organisms/100 ml (30-Day)	

Legend

m = metres
ml = millilitres
mg = milligrams
μg/cm^3 = micrograms per cubic metre
μCi/ml = microcuries per millilitre
pCi/g = picocuries per gram

NA = Not Applicable
RF = Rocky Flats
40-CFR-61 = National Emission Standards for Hazardous Air Pollutants, Part 61.(USEPA)
AECMC = AEC Manual Chapter
NPDES = National Pollutant Discharge Elimination System

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TABLE 3. Environmental Analysis Laboratory Measurement Control Data.

Element	Matrix	[a]Standard Sample Analysis Variation (percent)	Bias (percent)
Americium	Effluent Filters	19.7	7.1
Beryllium	Effluent Filters	127.3	- 1.2
Uranium	Effluent Filters	44.0	8.9
Plutonium	Effluent Filters	33.6	3.6
Americium	Surface Water	52.0	54.8
Uranium	Surface Water	41.7	7.3
Plutonium	Surface Water	58.2	8.2
Tritium	Surface Water	3.4	- 5.4

[a]Six-month moving average.

TABLE 4. Materials Released to Atmosphere.

1974	[a]Plutonium Facilities (microcuries)	[b]Uranium and Research Facilities (microcuries)	[c]Beryllium Facilities (grams)	Tritium Facilities (curies)
January	< 2.44	< 2.23	< 0.71	0.97
February	< 5.89	< 2.22	0.39	< 1.21
March	< 6.18	< 3.89	1.20	< 1.02
April	<934.12	< 4.04	0.87	1.00
May	< 0.42	< 3.69	3.17	0.95
June	< 3.42	< 3.03	1.38	0.57
July	< 0.56	< 1.90	2.29	0.65
August	< 0.56	< 2.31	0.22	0.71
September	< 0.50	< 1.37	0.23	< 2.58
October	< 0.81	< 3.90	0.15	< 0.39
November	< 0.35	< 7.29	0.20	< 0.29
December	< 0.38	<10.24	0.18	< 0.03
Total	<955.63	<46.11	<10.99	<10.38

[a] Radiochemically determined as plutonium.
[b] Radiometrically determined as total long-lived alpha activity.
[c] The U.S. Environmental Protection Agency discharge limitation for beryllium is 10 grams per day.

TABLE 5. Plutonium in Rocky Flats Ambient Air.

Station	Number of Samples Taken	Less than Detectable	Volume (cubic metres)	[a]Concentration ($\times 10^{-15}$ microcuries per millilitre) $C_{maximum}$	[b]$C_{average}$	[c]Percent of RCG_a
S-1	11	0	26,989.0	1.254	0.300 ± 73%	0.50
S-2	10	0	20,713.5	1.861	0.365 ± 122%	0.61
S-3	10	0	23,966.0	0.553	0.197 ± 60%	0.33
S-4	10	0	25,342.0	1.078	0.293 ± 71%	0.48
S-5	11	0	251,937.9	0.225	0.121 ± 35%	0.20
S-6	10	0	22,993.0	0.965	0.335 ± 57%	0.56
S-7	11	0	25,442.5	4.624	0.836 ± 108%	1.39
S-8	11	0	24,646.0	15.789	3.170 ± 94%	5.28
S-9	10	0	19,290.0	1.153	0.511 ± 46%	0.85
S-10	9	0	23,264.5	1.252	0.429 ± 62%	0.72
S-50	9	0	21,202.5	1.262	0.631 ± 38%	1.05
S-51	10	0	358,837.3	0.439	0.118 ± 80%	0.19
S-52	10	0	22,220.0	1.947	0.415 ± 111%	0.69
AF-83	8	0	248,098.3	2.966	1.153 ± 70%	1.92
AC-84	9	0	352,116.0	3.342	1.115 ± 90%	1.86
S-22	1	0	63,872.0	0.023	0.023 ± 0%	1.04
Summary	150	0	1,530,931.1	15.789	–	
Volume-Weighted Average					0.608 ± 39 percent	1.01

[a] Monthly Composite Station Concentrations.
[b] Volume-weighted average.
[c] The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air accessible to incidentally exposed individuals is 60×10^{-15} microcuries per millilitre.

TABLE 6. Total Long-Lived Beta Activity in Rocky Flats Ambient Air.

Station	Number of Samples Taken	Less than Detectable	Volume (cubic metres)	Concentration ($\times 10^{-12}$ microcuries per millilitre) $C_{maximum}$	[a]$C_{average}$	[b]Percent of RCG_a
S-1	69	8	10,387.0	1.0233 ± 61%	<0.1848 ± 33%	<0.19
S-2	69	29	6,657.5	0.5374 ± 85%	<0.1442 ± 20%	<0.14
S-3	72	17	7,928.5	0.7951 ± 70%	<0.1762 ± 26%	<0.18
S-4	68	7	7,717.5	1.0675 ± 60%	<0.2506 ± 25%	<0.25
[c]S-5	–	–	–	–	–	
S-6	71	19	7,535.5	0.6258 ± 78%	<0.1791 ± 24%	<0.18
S-7	72	13	7,660.5	0.8761 ± 66%	<0.2257 ± 24%	<0.23
S-8	71	20	7,394.5	0.7656 ± 71%	<0.1673 ± 23%	<0.17
S-9	67	11	6,710.0	0.9423 ± 64%	<0.2652 ± 22%	<0.27
S-10	71	13	8,418.5	1.0160 ± 61%	<0.2247 ± 30%	<0.22
S-50	70	17	7,725.5	1.0486 ± 61%	<0.2632 ± 22%	<0.26
[c]S-51	–	–	–	–	–	
S-52	67	17	8,290.0	1.5755 ± 49%	<0.1705 ± 36%	<0.17
Summary	767	171	86,425.0	1.5755 ± 49%		
Volume-Weighted Average					<0.2042 ± 8%	<0.20

[a] Volume-weighted average.
[b] The Radioactivity Concentration Guide (RCG_a) for total long-lived beta activity in ambient air accessible to incidentally exposed individuals is 100×10^{-12} microcuries per millilitre.
[c] New high-volume samplers. Radiometric counting equipment could not accommodate larger filter papers. Radiochemical analysis for plutonium was performed for samples from these stations.

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TABLE 7. Plutonium in Three- to Six-~~Metre~~ Kilometre (2- to 4-miles) Distant Ambient Air.

Station	Number of Samples Taken	Less than Detectable	Volume (cubic metres)	Concentration ($\times 10^{-15}$ microcuries per millilitre) $C_{maximum}$	Concentration ($\times 10^{-15}$ microcuries per millilitre) [a]$C_{average}$	[b]Percent of RCG_a
S-26	11	1	298,036.4	0.109	<0.046 ± 72%	<0.23
S-27	7	0	250,422.0	0.884	0.192 ± 212%	0.96
S-28	12	0	367,695.9	0.085	0.041 ± 53%	0.21
S-31	8	0	246,417.0	0.158	0.062 ± 119%	0.31
S-32	12	0	357,608.5	0.097	0.053 ± 50%	0.27
S-33	12	0	320,464.3	0.140	0.050 ± 76%	0.25
S-34	12	0	348,383.9	0.080	0.040 ± 47%	0.20
S-35	11	0	282,319.0	0.099	0.047 ± 54%	0.24
S-36	12	0	323,779.7	0.097	0.041 ± 65%	0.21
S-37	12	0	350,744.8	0.087	0.047 ± 51%	0.24
Summary	109	1	3,145,871.4	0.884	–	–
Volume-Weighted Average					<0.058 ± 39%	<0.29

[a] Volume-weighted average.
[b] The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air accessible to the population at large is 20×10^{-15} microcuries per millilitre.

TABLE 8. Plutonium in Community Ambient Air.

Community	Number of Samples Taken	Less than Detectable	Volume (cubic metres)	Concentration ($\times 10^{-15}$ microcuries per millilitre) $C_{maximum}$	Concentration ($\times 10^{-15}$ microcuries per millilitre) [a]$C_{average}$	[b]Percent of RCG_a
Boulder	10	0	30,612.8	0.366	0.105 ± 71%	0.53
Broomfield	11	0	31,899.7	0.168	0.079 ± 45%	0.40
Coal Creek	10	0	29,159.1	10.864	0.931 ± 265%	4.66
Denver	11	1	30,279.8	3.603	<0.406 ± 176%	<2.03
Golden	10	1	29,502.7	7.447	<0.908 ± 182%	<4.54
Lafayette	10	1	25,593.9	0.254	<0.090 ± 68%	<0.45
Marshall	5	1	11,211.0	0.190	<0.074 ± 113%	<0.37
Wagner	11	0	26,214.2	0.237	0.082 ± 51%	0.41
Westminster	6	0	13,570.0	0.176	0.072 ± 83%	0.36
Summary	84	4	228,043.2	10.864		
Volume-Weighted Average					<0.343 ± 92%	<1.72

[a] Volume-weighted average.
[b] The Radioactivity Concentration Guide (RCG_a) for plutonium in ambient air accessible to the population at large is 20×10^{-15} microcuries per millilitre.

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TABLE 9. Total Long-Lived Alpha and Beta Activity in Community Ambient Air.

Total Long-Lived Alpha Activity

Community	Number of Samples Taken	Less than Detectable	Volume (cubic metres)	Concentration ($\times 10^{-15}$ microcuries per millilitre) $C_{maximum}$	$^{a}C_{average}$	[b]Percent of RCG_a
Boulder	52	1	37,952.7	3.1 ±42%	<1.9 ± 9%	< 9.5
Broomfield	53	4	35,861.7	5.4 ±27%	<1.7 ±15%	< 8.5
Coal Creek	53	3	35,813.5	15.0 ±17%	<1.8 ±30%	< 9.0
Denver	53	2	34,276.2	5.6 ±34%	<2.0 ±16%	<10.0
Golden	53	2	35,955.2	17.9 ±15%	<2.4 ±27%	<12.0
Lafayette	51	4	30,748.3	4.0 ±34%	<1.8 ±15%	< 9.0
Marshall	24	7	12,246.0	3.6 ±39%	<1.5 ±22%	< 7.5
Wagner	53	1	29,545.5	7.8 ±24%	<2.5 ±16%	<12.5
Westminster	25	2	14,679.0	7.3 ±26%	<2.1 ±28%	<10.5
Summary	417	26	267,078.1	17.9 ±15%	-	-
Volume-Weighted Average					<2.0 ± 7%	<10.0

Total Long-Lived Beta Activity

				Concentration ($\times 10^{-12}$ microcuries per millilitre)		[c]Percent of RCG_a
Boulder	51	0	37,202.7	0.4124 ± 8%	0.152 ±18%	0.46
Broomfield	52	0	35,138.7	0.4461 ± 9%	0.152 ±18%	0.46
Coal Creek	52	0	35,141.5	0.4287 ± 9%	0.145 ±18%	0.44
Denver	52	2	33,604.2	0.4916 ± 9%	<0.141 ±20%	< 0.43
Golden	52	0	35,232.2	0.5379 ± 9%	0.152 ±19%	0.46
Lafayette	50	3	30,177.3	0.3594 ±11%	<0.126 ±19%	< 0.38
Marshall	24	1	12,246.0	0.3448 ±12%	<0.168 ±25%	< 0.51
Wagner	52	0	28,952.5	0.4361 ± 9%	0.148 ±19%	0.45
Westminster	25	2	14,679.0	0.4139 ±10%	<0.170 ±28%	< 0.52
Summary	410	8	262,374.1	0.5379 ± 9%	-	-
Volume-Weighted Average					<0.148 ± 6%	< 0.45

[a] Volume-weighted average.
[b] The Radioactivity Concentration Guide (RCG_a) for soluble plutonium in ambient air accessible to the population at large is 20×10^{-15} microcuries per millilitre.
[c] The Radioactivity Concentration Guide (RCG_a) for total long-lived beta activity in ambient air accessible to the population at large is 33×10^{-12} microcuries per millilitre.

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TABLE 10. Average Concentrations of Chemical and Biological Constituents of Sewage Treatment Plant Effluent.

January through September 1974, Monitored at Pond B-4.

Parameter	Average Concentration	Most Restrictive Standard	[a]Agency	Percent of Standard
pH	7.6	6.0 to 9.0	CDH	In Range
Fecal Coliform Count	0/100 ml	200/100 ml	USEPA	In Range
Dissolved Oxygen	6.7 mg/l	> 2.0 mg/l	CDH	In Range
Residual Chlorine	0.4	0.1		400
Suspended Solids	31.2	30		104
Biochemical Oxygen Demand, 5-Day	15.3	30		51
Turbidity	[b]24 JTU	30 JTU		80
Color	48 Units	30 Units		160

October and November 1974, Monitored at Pond B-4.

		[c]NPDES Permit Secondary Treatment Standard		
pH	7.6	6.0 to 9.0	USEPA	In Range
Fecal Coliform Count	0/100 ml	200/100 ml		In Range
Dissolved Oxygen	9.0 mg/l	> 4.0 mg/l		In Range
Residual Chlorine	< 0.1	0.1		In Range
Suspended Solids	14.5	30		50
Biochemical Oxygen Demand, 5-Day	14.5	30		50
Phosphorus as P	2.4	8		30
Nitrate as N	4.5	20		23
Fluoride	0.7	< 1.7		41
Total Chromium	< 0.05	< 0.1		In Range
Oil and Grease	1.4	<10		13
Turbidity	4 JTU	30 JTU	CDH	13
Color	9 Units	30 Units	CDH	30

December 1974, Monitored at Discharge Points 001, 002, 003.

		Average Quantity	NPDES Permit Tertiary Treatment Standard		
[d]*Discharge Point 001:*					
pH	6.9	[e]NA	6.0 to 9.0	USEPA	In Range
Fecal Coliform Count	1.9/100 ml		200/100 ml		In Range
Dissolved Oxygen	8 mg/l		> 4 mg/l		In Range
Residual Chlorine	< 0.1		0.1		In Range
Suspended Solids	5	3.39 kg/day	15		33
Biochemical Oxygen Demand, 5-Day	9	5.94 kg/day	10		90
Phosphorus as P	4	NA	8		50
Nitrate as N	11	7.24 kg/day	10		110
Fluoride	0.5	NA	1.7		29
Total Chromium	No Analysis		0.05		–
Oil and Grease	0.4 mg/l		10		4
Turbidity	6 JTU		30 JTU	CDH	20
Color	10 Units		30 Units	CDH	33
Discharge Point 002:					
pH	7.8	NA	6.0 to 9.0	USEPA	In Range
Nitrate as N	1.5 mg/l	NA	10 mg/l	USEPA	15
Discharge Point 003:					
Nitrate as N	1 mg/l	NA	NA	USEPA	
Total Dissolved Solids	194 mg/l				
pH	6.2				
Chemical Oxygen Demand	27 mg/l	NA	NA	USEPA	

[a] CDH – Colorado Department of Health, Water Pollution Control Commission, Denver, Colorado.
USEPA – U. S. Environmental Protection Agency, Washington, D. C. (Region Office VIII, Denver, Colorado).
[b] JTU – Jackson Turbidity Unit.
[c] NPDES – Permit issued by National Pollutant Discharge Elimination System, Washington, D. C.
[d] The USEPA-NPDES discharge permit defines Discharge Points 001, 002, and 003 as the Sewage Treatment Plant, Pond A-3, and Pond C-1, respectively.
[e] NA = Not Applicable; ml = millilitre; mg/l = milligrams per litre; kg/day = kilograms per day.

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TABLE 11. Plutonium, Uranium, and Americium in Rocky Flats Holding Ponds.

	Plutonium Concentration ($\times 10^{-9}$ microcuries per millilitre)				Uranium Concentration ($\times 10^{-9}$ microcuries per millilitre)				Americium Concentration ($\times 10^{-9}$ microcuries per millilitre)			
Pond	$C_{minimum}$	$C_{maximum}$	[a]$C_{average}$	[b]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[c]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[d]Percent of RCG_w
A-3	0.061	1.140	0.253 ± 42%	0.02	0.481	16.950	3.756 ± 61%	0.04	<0.040	0.216	<0.070 ± 38%	<0.01
B-4	0.200	9.000	1.780 ± 29%	0.11	1.140	19.880	5.173 ± 1%	0.05	<0.040	2.990	<0.493 ± 30%	<0.04
C-1	<0.040	1.810	<0.155 ± 46%	<0.01	<0.040	10.870	<2.441 ± 37%	<0.02	<0.040	4.500	<0.246 ± 115%	<0.02

[a] Volume-weighted average.
[b] The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1,667 × 10^{-9} microcuries per millilitre.
[c] The Radioactivity Concentration Guide (RCG_w) for soluble uranium is 10,000 × 10^{-9} microcuries per millilitre.
[d] The Radioactivity Concentration Guide (RCG_w) for soluble americium is 1,330 × 10^{-9} microcuries per millilitre.

TABLE 12. Plutonium, Uranium, and Americium in Walnut Creek.

	Plutonium Concentration ($\times 10^{-9}$ microcuries per millilitre)				Uranium Concentration ($\times 10^{-9}$ microcuries per millilitre)				Americium Concentration ($\times 10^{-9}$ microcuries per millilitre)			
Location	C_{min}	C_{max}	[a]C_{avg}	[b]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[c]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[d]Percent of RCG_w
Walnut Creek at Indiana Street	0.043	7.330	0.843 ± 48%	0.05	0.640	18.990	3.691 ± 33%	0.04	<0.040	1.700	<0.230 ± 48%	<0.02

[a] Sample-weighted average.
[b] The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is 1,667 × 10^{-9} microcuries per millilitre.
[c] The Radioactivity Concentration Guide (RCG_w) for soluble uranium is 10,000 × 10^{-9} microcuries per millilitre.
[d] The Radioactivity Concentration Guide (RCG_w) for soluble americium is 1,330 × 10^{-9} microcuries per millilitre.

TABLE 13. Tritium in Water Samples.

	Tritium Concentrations ($\times 10^{-6}$ microcuries per millilitre)			
Station	$C_{minimum}$	$C_{maximum}$	[a]$C_{average}$	[b]Percent of RCG_w
Pond A-3	<0.500	17.086	<1.314 ± 23%	<0.131
Pond B-4	<0.500	6.374	<1.556 ± 6%	<0.156
Pond C-1	<0.500	7.368	<0.909 ± 10%	<0.091
Walnut Creek at Indiana Street	<0.500	10.287	<2.035 ± 7%	<0.204
Great Western Reservoir	0.543	17.801	6.070 ± 17%	0.607
Standley Lake	<0.500	6.673	<1.056 ± 34%	<0.106

[a] Sample-weighted average.
[b] The Radioactivity Concentration Guide (RCG_w) for tritium in water released to uncontrolled areas is 1,000 × 10^{-6} microcuries per millilitre.

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TABLE 14. Groundwater Monitoring. (Averages of 1974 last quarter samples.)

Well No.	Depth per Feet	Concentrations of Radioactive Materials ($\times 10^{-9}$ microcuries per millilitre) Plutonium [a](PHA)	Tritium	Long-lived Alpha	Long-lived Beta	Concentrations of Chemical Parameters (parts per million) Hardness	[b](micro-mho) Conductivity	Total Dissolved Solids	Nitrate	Nitrite
1-66	148	Dry ?								
2-66	146	Dry ?								
3-66	153	Dry ?								
1-60	23	ND	1,000	88	60	4,600	8,700	8,364	2,700	0.47
2-60	30	<0.10	5,000	98	177	4,000	15,200	12,886	7,000	0.46
3-60	30	<0.10	8,000	43	14	630	1,490	1,125	260	<0.01
4-60	30	0.18	6,500	29	40	450	1,420	1,170	492	0.06
5-60	30	Dry								
6-60	30	<0.16	12,000	72	40	320	700	471	5	<0.01
1-71	30	Dry								
2-71	30	Dry								
3-71	25	ND	1,500	21	30	150	880	560	< 1	<0.01
4-71	22	ND	< 338	22	10	38	400	244	5	<0.01
5-71	28	Dry ?								
6-71	28	Dry ?								
1-74	24	<0.10	< 428	98	1.3×10^3	216	440	272	22	0.01
2-74	10	Dry								
3-74	24	ND	< 438	33	1.2×10^3	226	490	316	9	<0.01
4-74	6	Dry								
5-74	18	Dry								
6-74	7	Dry								
7-74	50	ND	< 434	85	2.2×10^2	224	450	274	6	<0.01
8-74	40	Dry								
9-74	19	Dry								
10-74	10	Dry								
11-74	20	ND	< 429	59	71	244	590	364	1	<0.01
12-74	4	Dry								
13-74	19	<0.10	< 437	1.1×10^2	74	210	820	536	1	<0.01
14-74	4	<0.10	< 474	69	1.3×10^2	147	500	322	44	<0.01
15-74	19	<0.10	< 436	1.7×10^2	18	542	1,400	974	1	<0.01
16-74	4	Dry								
17-74	16	ND	9,000	81	15	701	1,920	1,476	1	0.06
18-74	7	<0.10	< 475	1.1×10^2	90	548	1,610	1,278	1	<0.01
19-74	16	~~Dry~~ abandoned								
20-74	10	~~Dry~~ "								
21-74	265	0.18	< 458	1.1×10^2	14	55	280	229	1	0.08
22-74	315	0.18	< 478	69	2.0×10^2	76	350	234	6	<0.01

[a] All samples were initially screened for plutonium by liquid scintillation spectrometry. Samples showing no detected activity are indicated by ND. Samples showing detectable activity by liquid scintillation spectrometry were further analyzed by alpha pulse height (PHA) spectrometry following separation of the plutonium by ion-exchange chromatography.

[b] For SI (metric) use: 1 mho (conductance) = 1 siemen.

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TABLE 15. Uranium plus Plutonium and Plutonium in Public Water Supplies.

[a]Annual Average Concentrations ($\times 10^{-9}$ microcuries per millilitre).

Reservoirs	Number of Samples	Uranium plus Plutonium				Plutonium			
		C_{min}	C_{max}	[a]C_{avg}	[b]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[c]Percent of RCG_w
Great Western	11	<0.01	2.59	<0.55 ± 105%	<0.01	<0.01	0.07	<0.02 ± 55%	<0.001
Standley Lake	10	<0.01	6.50	<1.09 ± 132%	<0.01	<0.01	0.10	<0.02 ± 98%	<0.001
Reservoir Summary	21	<0.01	6.50	–	–	<0.01	0.10		
Reservoir Average		–	–	<0.82 ± 68%	<0.01	–	–	<0.02 ± 0%	<0.001
Finished Water									
Arvada	12	<0.01	4.83	<1.36 ± 89%	<0.01	<0.01	0.41	<0.05 ± 147%	<0.003
Boulder	11	<0.01	3.09	<0.70 ± 101%	<0.01	<0.01	2.31	<0.31 ± 153%	<0.019
Broomfield	12	<0.01	2.17	<0.47 ± 93%	<0.01	<0.01	0.23	<0.03 ± 133%	<0.002
Denver	12	<0.01	3.30	<0.73 ± 111%	<0.01	<0.01	0.05	<0.02 ± 52%	<0.001
Golden	12	<0.01	3.67	<0.79 ± 112%	<0.01	<0.01	1.15	<0.19 ± 124%	<0.011
Lafayette	12	<0.01	1.19	<0.39 ± 69%	<0.01	<0.01	0.14	<0.02 ± 114%	<0.001
Louisville	12	<0.01	0.87	<0.32 ± 61%	<0.01	<0.01	0.02	<0.01 ± 16%	<0.001
Thornton	12	<0.01	13.93	<2.37 ± 126%	<0.02	<0.01	0.14	<0.02 ± 104%	<0.001
Westminster	12	<0.01	1.19	<0.16 ± 133%	<0.01	<0.01	0.03	<0.01 ± 32%	<0.001
Finished Water Summary	107	<0.01	13.93	–	–	<0.01	2.31	–	
Finished Water Average		–	–	<0.81 ± 55%	<0.01	–	–	<0.07 ± 89%	<0.004

[a] Sample-weighted average.

[b]The Radioactivity Concentration Guide (RCG_w) for soluble uranium plus plutonium in water is given by:

$$\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$$

Where, $RCG_U = 10{,}000 \times 10^{-9}$ microcuries per millilitre
and $RCG_{Pu} = 1{,}667 \times 10^{-9}$ microcuries per millilitre.

[c]The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is $1{,}667 \times 10^{-9}$ microcuries per millilitre.

TABLE 16. Uranium plus Plutonium and Plutonium in Regional Lakes, Reservoirs, and Streams.

[a]October 1974 Average Concentrations ($\times 10^{-9}$ microcuries per millilitre).

Distance from Rocky Flats Plant	Number of Samples	Uranium plus Plutonium				Plutonium			
		C_{min}	C_{max}	[a]C_{avg}	[b]Percent of RCG_w	C_{min}	C_{max}	[a]C_{avg}	[c]Percent of RCG_w
Less than 5 miles	11	<0.10	9.00	<2.46 ± 90%	0.02	<0.10	<0.10	<0.10 ± 0%	<0.01
Greater than 5 miles	19	<0.10	14.87	<2.46 ± 90%	0.02	<0.10	1.11	0.15 ± 72%	<0.01
Summary of all samples	30	<0.10	14.87	–	–	<0.10	1.11		
[a]Average of all samples		–	–	<2.46 ± 63%	0.02	–	–	<0.13 ± 51%	<0.01

[a] Sample-weighted average.

[b]The Radioactivity Concentration Guide (RCG_w) in water for soluble uranium plus plutonium is given by:

$$\frac{C_U}{RCG_U} + \frac{C_{Pu}}{RCG_{Pu}} \leq 1$$

Where, $RCG_U = 10{,}000 \times 10^{-9}$ microcuries per millilitre
and $RCG_{Pu} = 1{,}667 \times 10^{-9}$ microcuries per millilitre.

[c]The Radioactivity Concentration Guide (RCG_w) for soluble plutonium in water is $1{,}667 \times 10^{-9}$ microcuries per millilitre.

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TABLE 17. Estimated Dose Commitment to the General Population.

Analysis and Location	Average Concentration (C_{avg}) (microcuries per cubic centimetre)	RCG_a or RCG_w (microcuries per cubic centimetre)	Annual Dose Commitment (millirems)
Plutonium in Air (2- to 4-mile locations)	$<0.058 \pm 39\% \times 10^{-15}$	20×10^{-15}	< 2.91
Plutonium in Water (Walnut Creek and Indiana Street)	$0.843 \pm 48\% \times 10^{-9}$	1667×10^{-9}	0.57
Uranium in Water (Walnut Creek and Indiana Street)	$3.691 \pm 33\% \times 10^{-9}$	a	a
Tritium (^3H) in Water (Walnut Creek and Indiana Street)	$<2.035 \pm 7\% \times 10^{-6}$	1000×10^{-6}	< 0.34
		Plant Perimeter Total	< 3.82
Plutonium in Air (Community)	$<0.343 \pm 92\% \times 10^{-15}$	20×10^{-15}	<17.2
Plutonium in Water (Community)	$<0.07 \pm 89\% \times 10^{-9}$	1667×10^{-9}	< 0.04
Uranium in Water (Community)	$<0.74 \pm 89\% \times 10^{-9}$	a	a
Tritium (^3H) in Great Western Reservoir	$6.070 \pm 17\% \times 10^{-6}$	1000×10^{-6}	1.01
Tritium (^3H) in Standley Lake	$<1.056 \pm 34\% \times 10^{-6}$	1000×10^{-6}	< 0.18
		Community Total including Great Western Reservoir	<18.3
		Community Total including Standley Lake	<17.4

[a] The values for uranium in plant effluent water and community water were less than that for raw influent water. Therefore, no dose commitments were caused from plant operations.

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ILLUSTRATIONS

FIGURES 1 through 12

FIGURE 1. Location of the Rocky Flats Plant and Surrounding Communities.

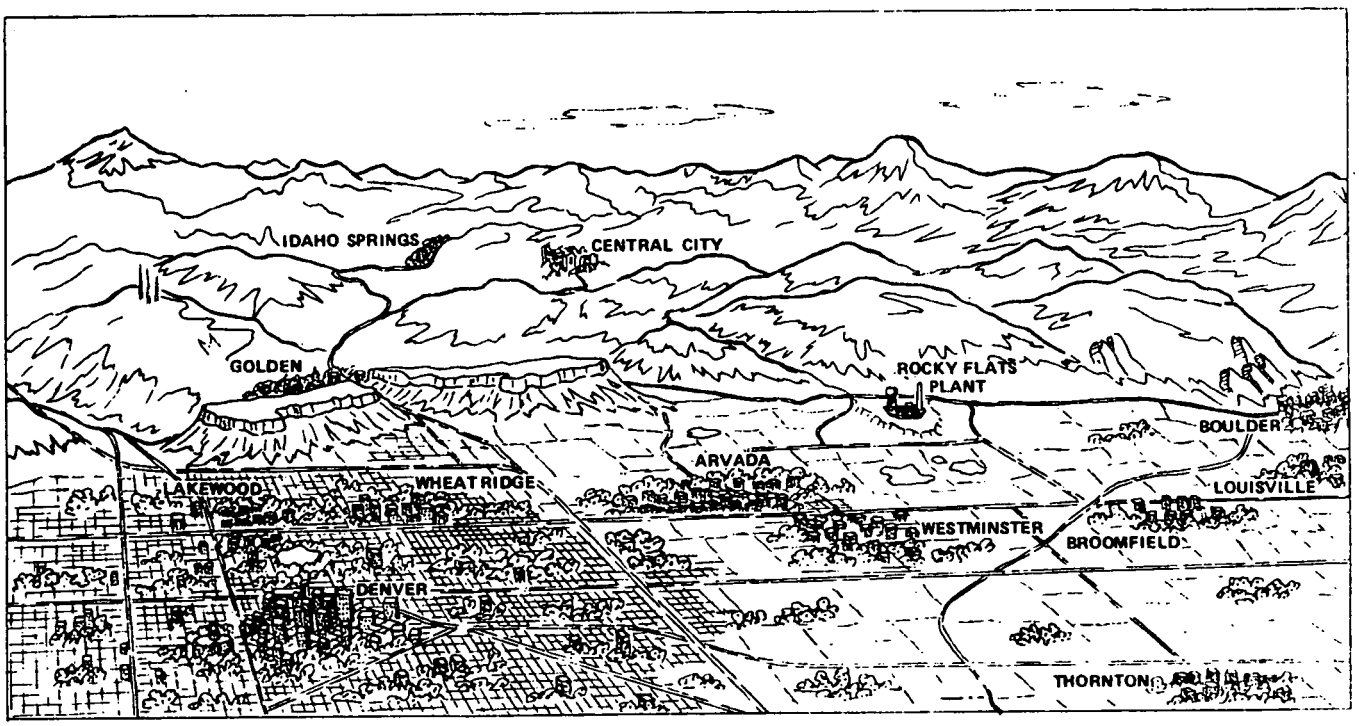

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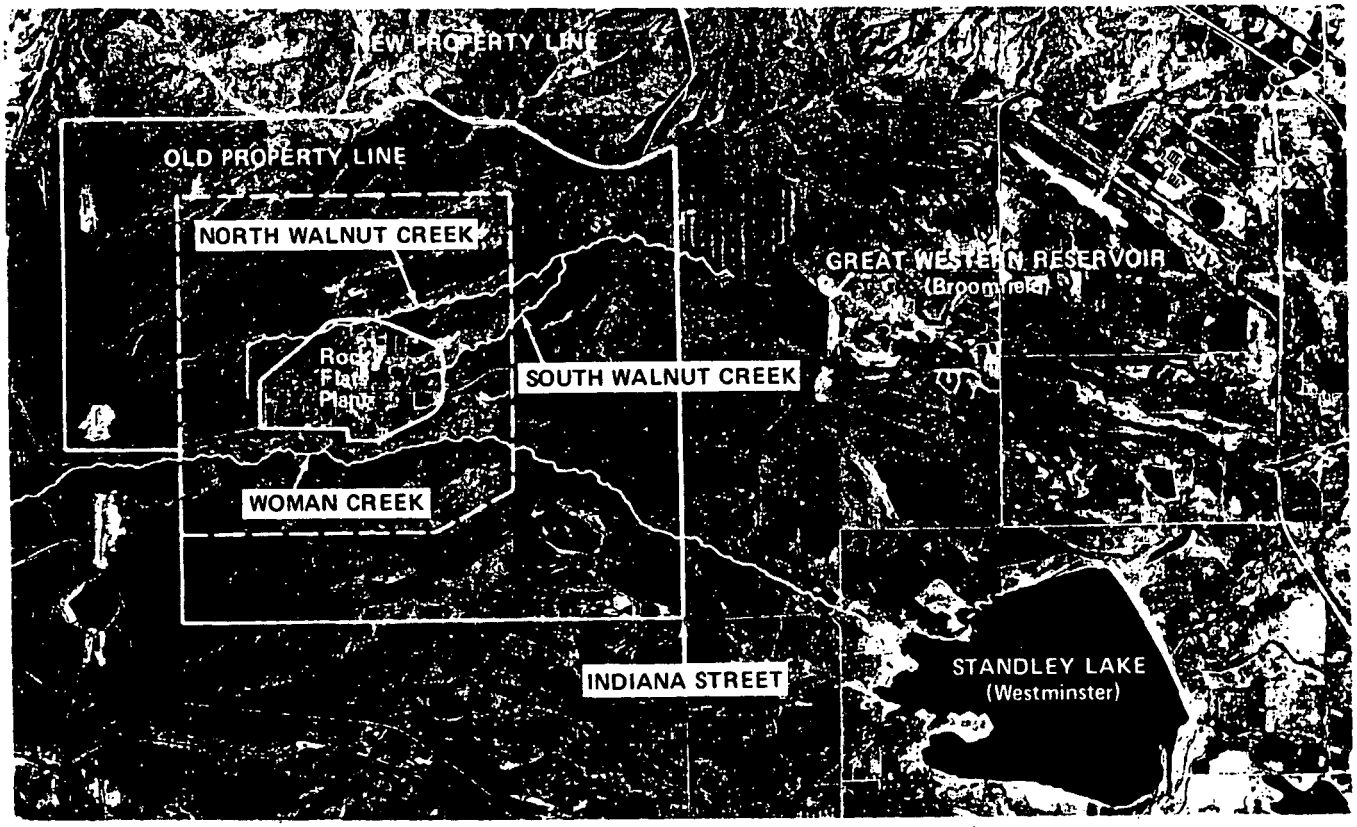
FIGURE 2. Location of the Rocky Flats Plant Boundaries.

15299



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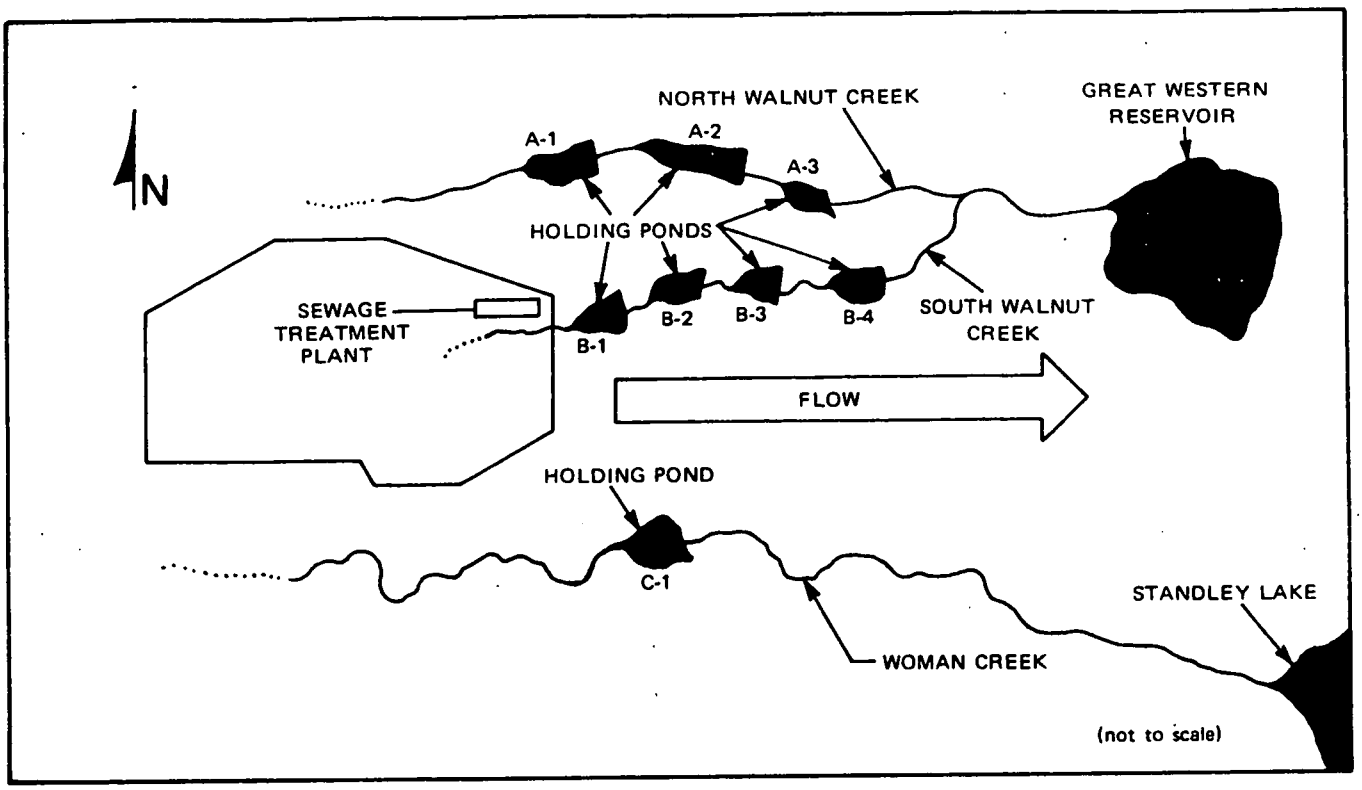

FIGURE 3. Liquid Effluent Watercourses.

FIGURE 4. The 1974 Wind Rose.

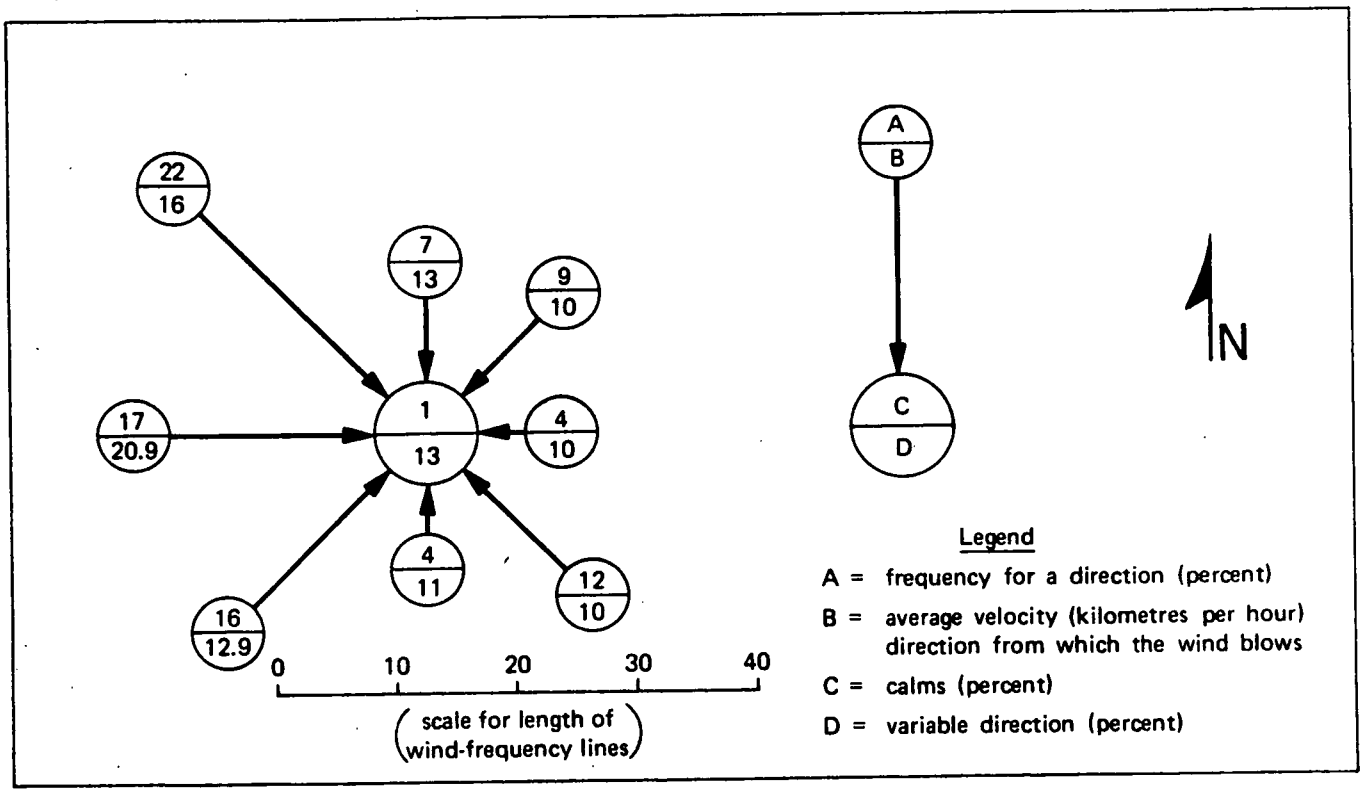

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FIGURE 5. Location of On-Site Ambient Air Samplers.

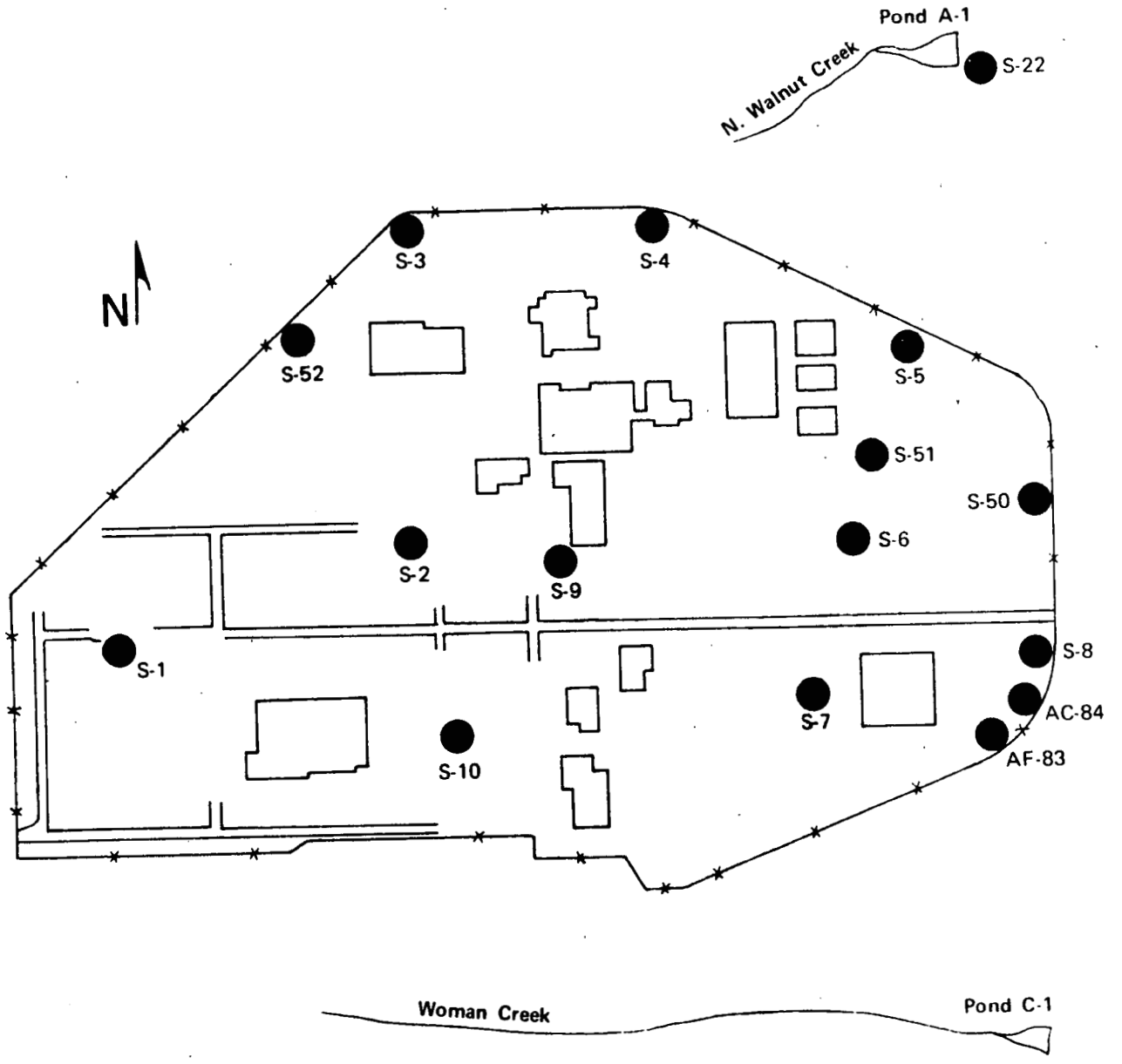

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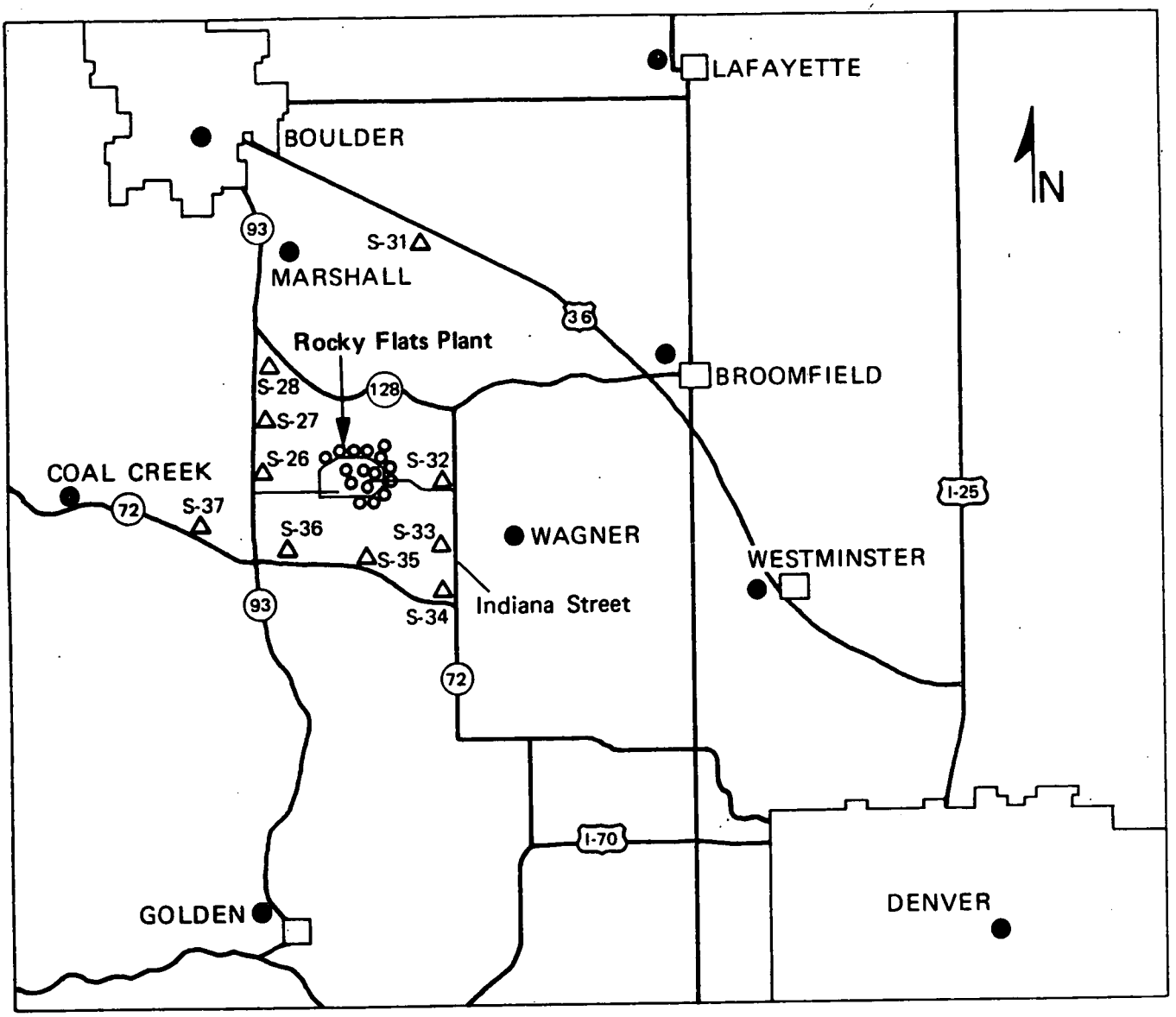
FIGURE 6. Location of Off-Site Ambient Air Samplers.



Legend

● – Community Samplers.

o – On-Site Samplers.

△ – Samplers, 3 to 6 kilometres (2 to 4 miles) distance.

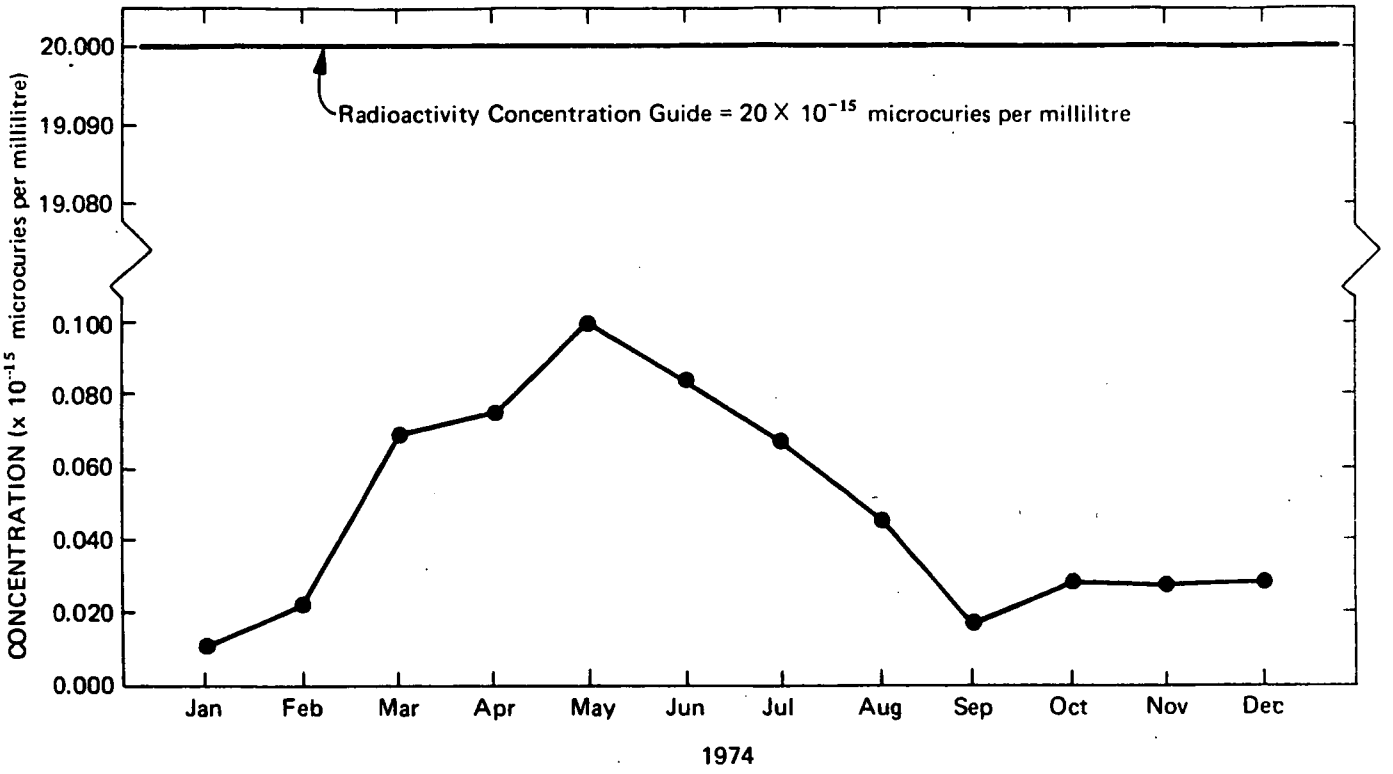
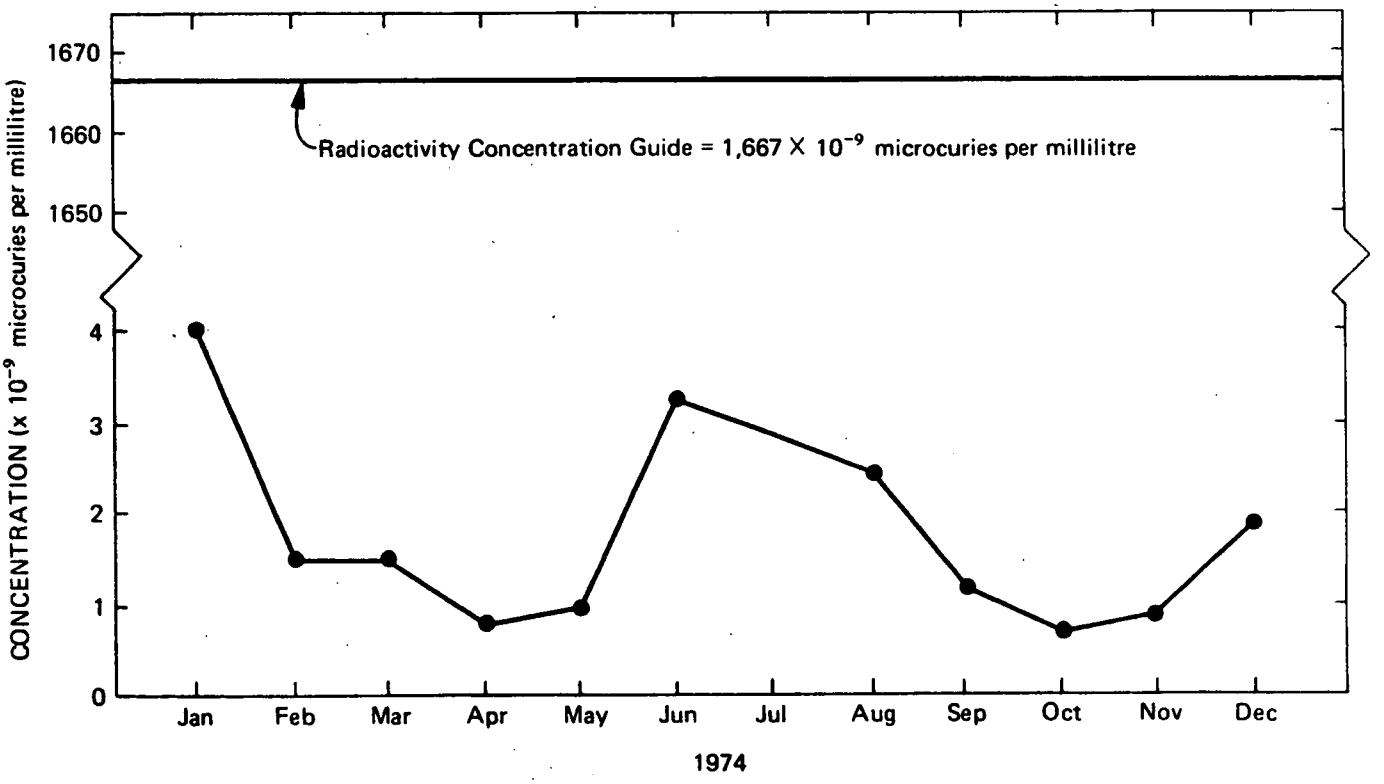


FIGURE 7. Plutonium in Three- to Six-Metre (2- to 4-miles) Distant Ambient Air Samples.

FIGURE 8. Plutonium in Pond B-4 Water Samples.



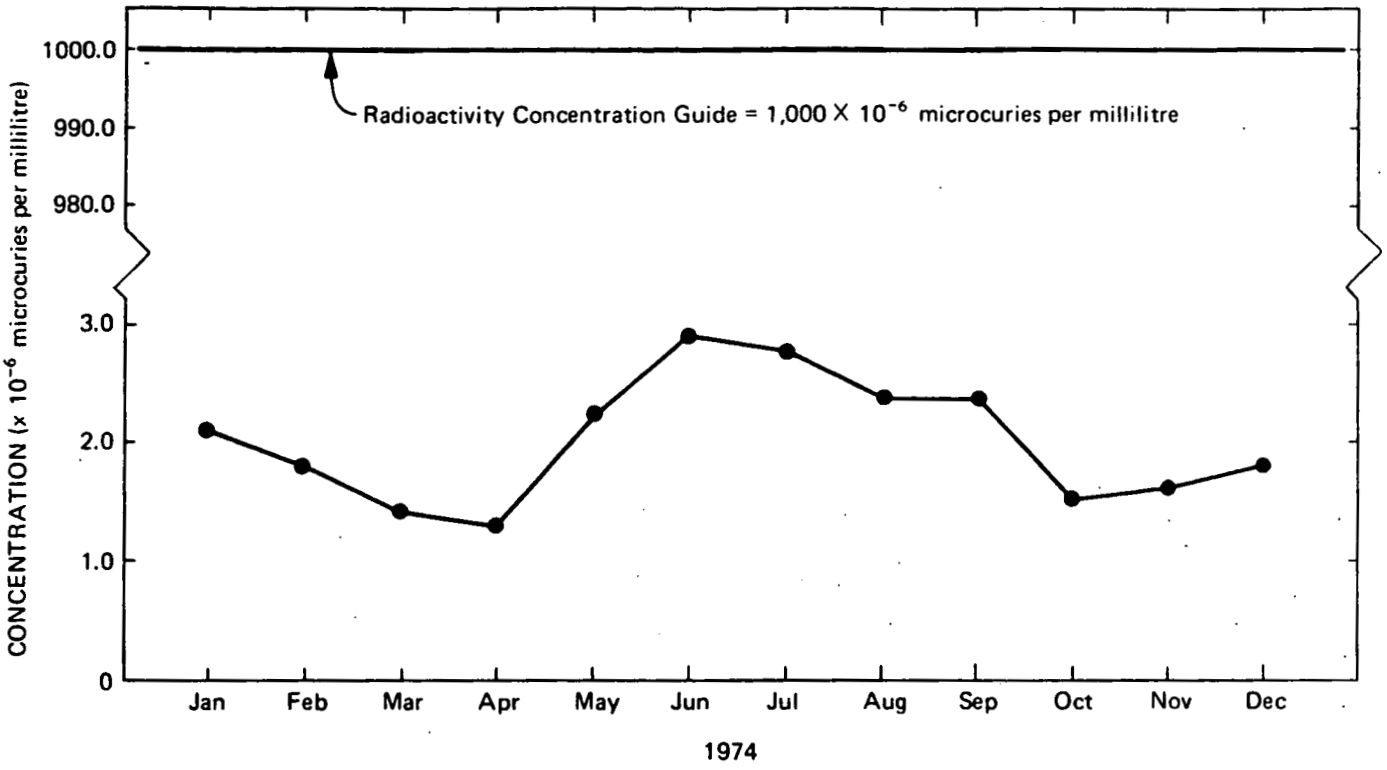


FIGURE 9. Tritium Concentrations in Walnut Creek.

FIGURE 10. Tritium Concentrations in Great Western Reservoir and Standley Lake.

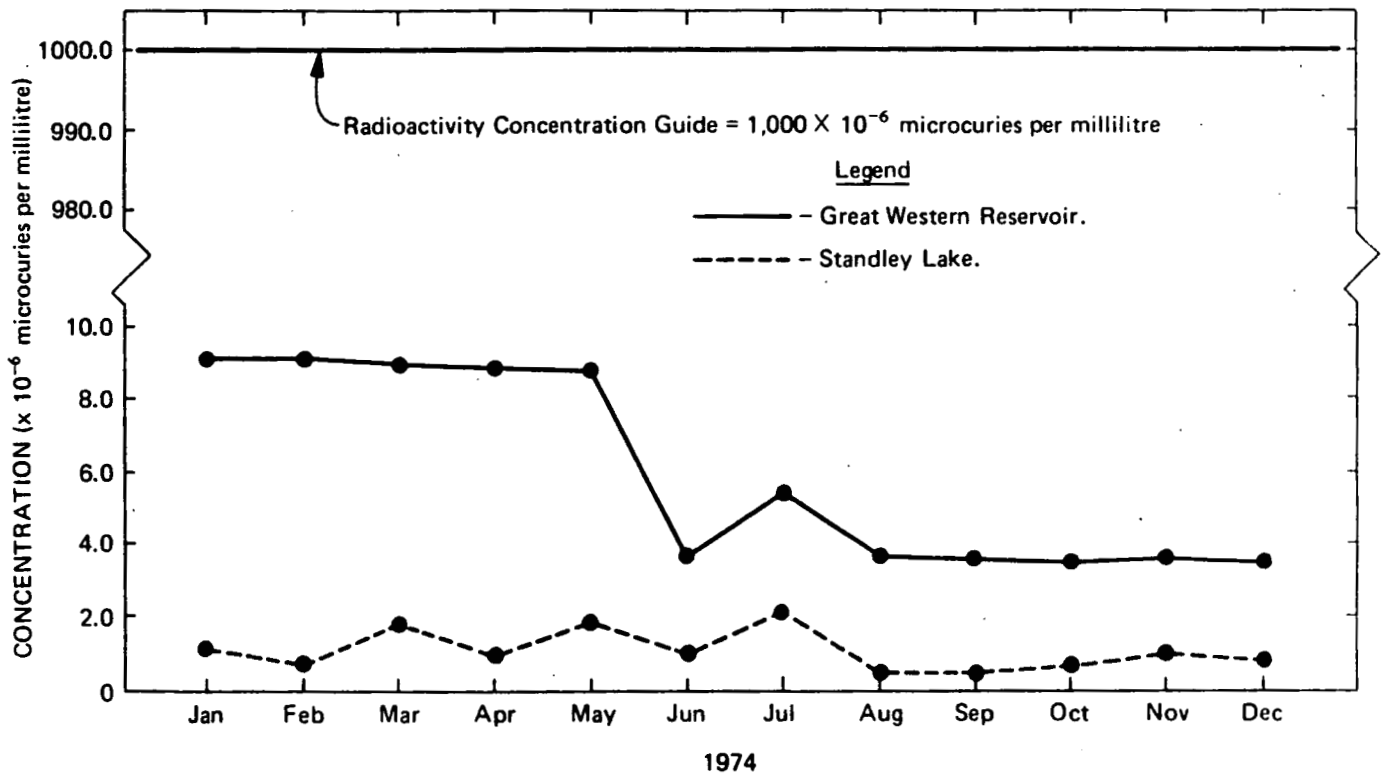


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FIGURE 11. Location of Goundwater Sampling Wells.

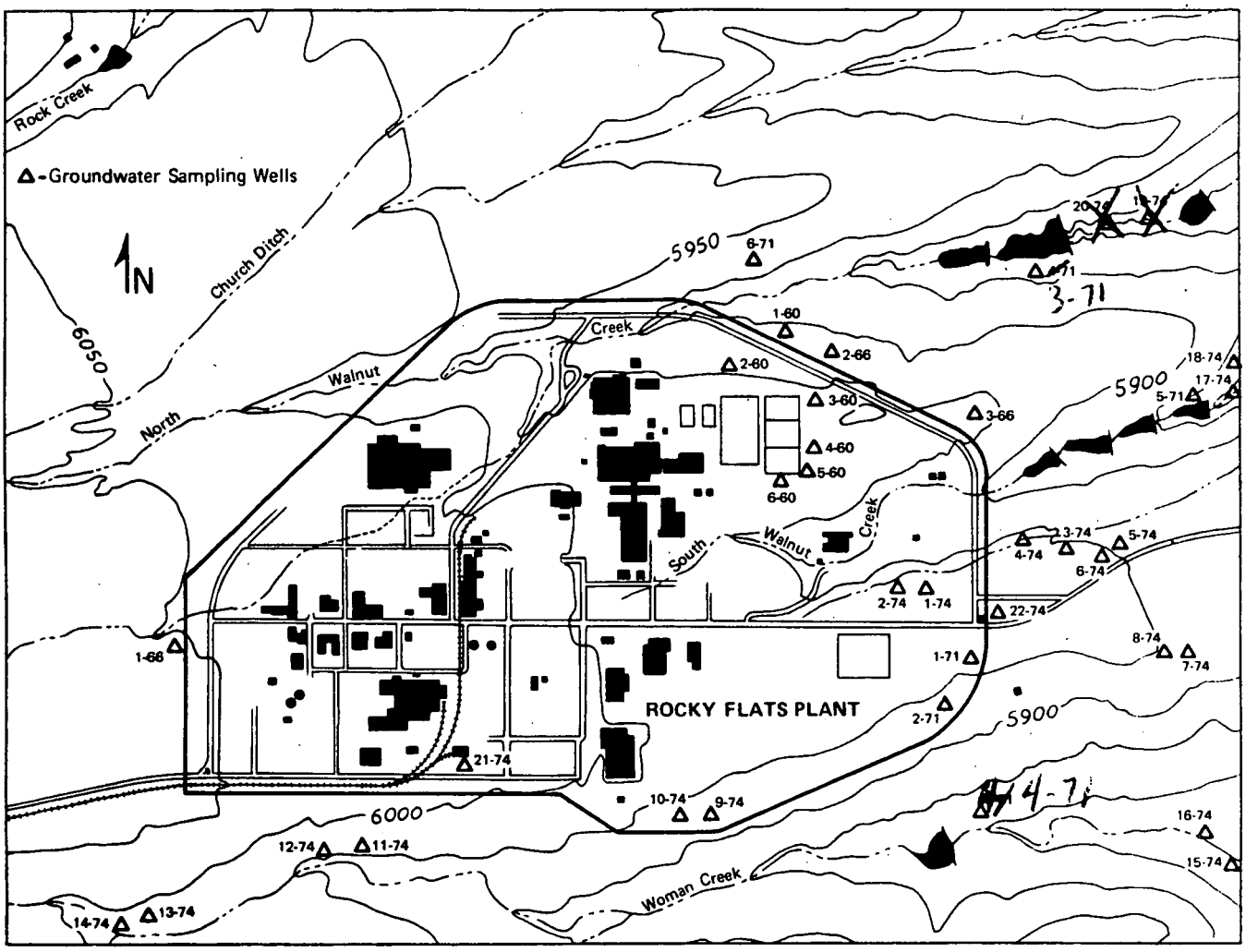
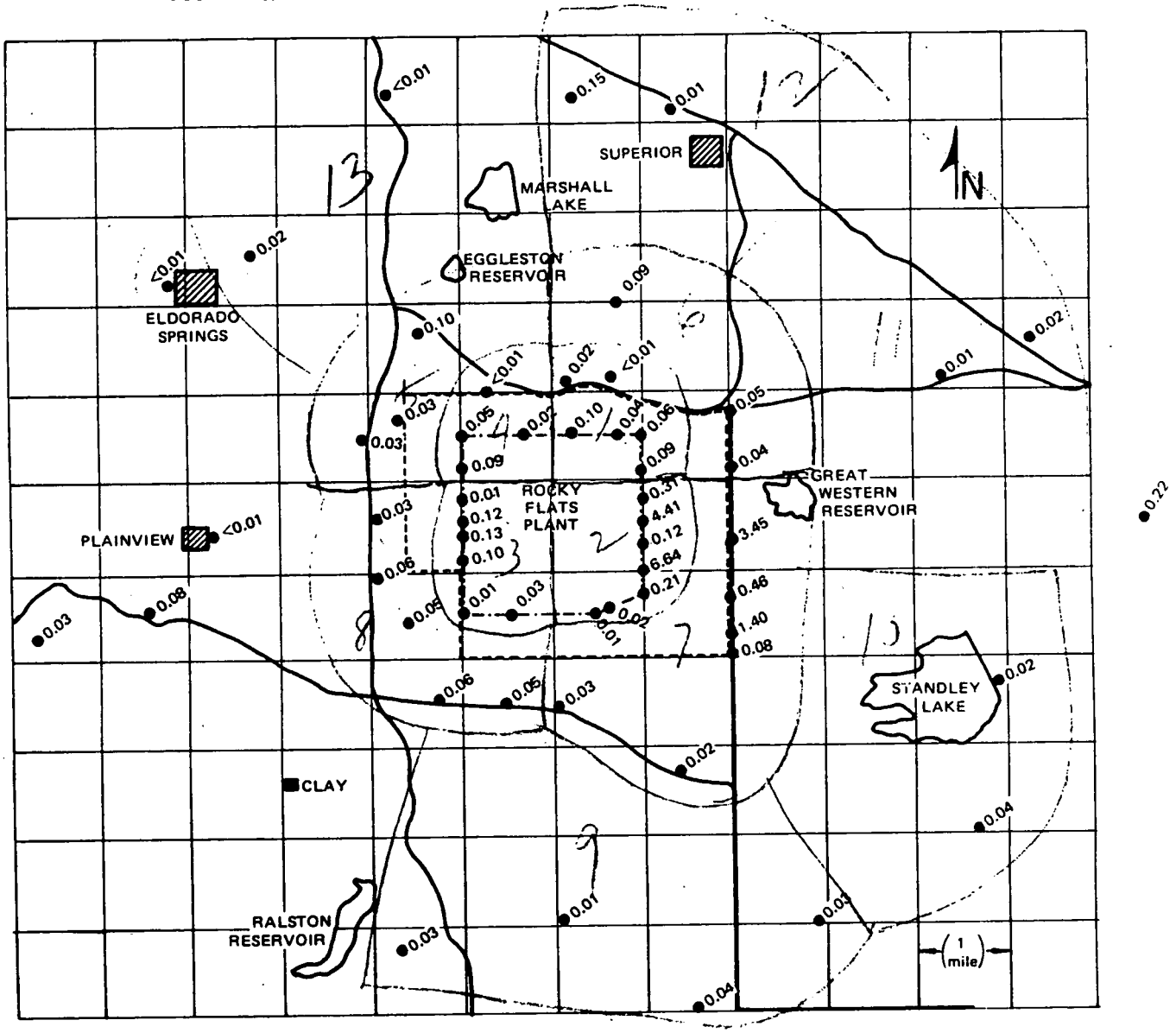


FIGURE 12. Plutonium Concentrations in Soil. (Values in picocuries per gram.)



dl/m/g = pCi/g × 2

μCi/m² = pCi/g × .01

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